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ORIGINAL ARTICLE

Influence of vertical soft tissue thickness on occurrence of peri-implantitis in patients with periodontitis: a prospective cohort study

Zhong Zhang BDS | Dong Shi DDS | Huanxin Meng PhD | Jie Han DDS | Li Zhang DDS | Wenjing Li BDS

Department of Periodontology, Peking University School and Hospital of Stomatology, Beijing, China

Correspondence
Huanxin Meng and Jie Han, Department of Periodontology, Peking University School and Hospital of Stomatology, 22 Zhongguancun Nandajie, Haidian District, Beijing 100081, China.
Email: kqhxmeng@bjmu.edu.cn (H. M.) and han_jie17@sina.com (J. H.)

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Abstract

Background: The influence of vertical soft tissue thickness on health of peri-implant tissue has been addressed in few studies; thus, further research is needed.

Purpose: To evaluate the influence of vertical soft tissue thickness on the risk of peri-implantitis and peri-implant condition in patients with a history of periodontitis.

Design/Methods: A total of 92 patients with a history of periodontitis were included in this study. During the implant placement, the distance from palatal soft tissue edge to the alveolar crest, which was defined as vertical soft tissue thickness, was measured. The characteristics of patients and implants were recorded at baseline (T1). After more than 2 years follow-up period, 65 patients with 159 implants finally came back for T2 evaluation, and parameters of peri-implant tissue were recorded. The associations of vertical soft tissue thickness with peri-implant parameter and occurrence of peri-implantitis were analyzed using the generalized estimating equation accompanying linear regression and logistic regression. In addition to conventional multivariate analysis, a propensity score for adjustment was used to reduce confounding bias.

Results: At follow-up examination (T2), survival rate at implant-level was 98.8%. The peri-implant parameters, including peri-implant probing depth and marginal bone loss, increased significantly with the increasing of soft tissue thickness ($P < 0.05$) after adjusting for a propensity score. In multivariate analysis adjusted for different confounding factors and propensity score, the odd ratios were all approximately 2.5, which meant that the risk of peri-implantitis increased 1.5 times for 1 mm increase of soft tissue thickness.

Conclusions: The excessive vertical soft tissue thickness around implants in patients with history of periodontitis has an adverse influence on health of the peri-implant tissue. This observation raises an important question on the association between vertical soft tissue thickness during implant surgery and history of periodontitis. Effective approaches to prevent the adverse effect of excessive soft tissue thickness on peri-implant tissue are necessary to be further investigated.

Zhong zhang and Dong Shi are the co-first authors of this article.

KEYWORDS
dental implants, peri-implant bone loss, peri-implantitis, vertical soft tissue thickness

1 | INTRODUCTION

Nowadays, oral rehabilitation with dental implants is becoming the preferred method for partially or totally edentulous patients, and demonstrated a favorable long-term survival rate. Jung et al.[1] reported that 10-year survival rate of implants supporting single crowns amounted to 95.2%, based on their meta-analysis. Meta-analysis published by Pjetursson et al.[2] indicated that estimated survival of implants supporting fixed dental prostheses was 93.1% after 10 years loading. However, good survival rate of dental implants does not always mean that the peri-implant condition is in a healthy status. Along with wide application of dental implants, the emergence of peri-implant disease cannot be ignored. According to meta-analysis of Chun-Teh Lee, mean prevalences of peri-implantitis and peri-implant mucositis are 19.83% and 46.83% in patient level, respectively.[3] The health status of the peri-implant tissues and its influence factors has become more and more concerned by clinicians and patients.

Peri-implant disease is an inflammatory lesion that occurs in the peri-implant's tissue and is associated with dental plaque, including peri-implant mucositis which only involves the peri-implant's soft tissue and peri-implantitis which involves both peri-implant's soft and hard tissue. The consensus report of the sixth European Workshop on Periodontology revealed that approximately 80% of the patients and 50% to 90% of the implants suffered from peri-implant mucositis. The prevalence of peri-implantitis was 28% to 56% in patient level and 12% to 43% in implant level.[4]

Hämmerle et al.[5] reported risk indicators for peri-implant diseases in details. Periodontitis, especially severe periodontitis, is a significant risk factor affecting peri-implant's health.

A 10-year prospective cohort study comparing clinical outcomes of implant treatment in patients with and without a history of chronic periodontitis demonstrated that survival rate of implants in patients with a history of periodontitis was lower than that in patients without a history of periodontitis (90.5% vs 96.5%), and the prevalence of peri-implantitis in patients with a history of periodontitis was higher than that without a history of periodontitis (28.6% vs 5.8%). There was a significant difference between two groups ($P < 0.05$).[6] Karoussis et al.[7] published a review about dental implant prognosis in periodontally compromised partially edentulous patients. In this review, authors discussed and concluded that patients with a history of chronic periodontitis may exhibit significantly greater long-term probing pocket depth, peri-implant marginal bone loss and prevalence of peri-implantitis compared with periodontally healthy patients. Xie et al.[8] reported that implants placed in patients with a history of severe periodontitis had significantly higher odds rate (OR 10) for peri-implant disease (peri-implant probing depth ≥ 5 mm and peri-implant bleeding on probing positive) compared to implants in patients without periodontitis.

A large number of clinical studies have shown that history of periodontitis has an adverse influence on the long-term survival rate of implants and the prevalence of peri-implantitis, but the mechanism of association between periodontitis and peri-implant disease is still unclear.

It is well known that periodontitis can significantly remodel the morphology of soft and hard tissues. Previous studies have indicated that morphology of soft tissue influences the health and behavior of peri-implant's tissue, especially during tissue integration of implants.

As early as 1996, Berglundh and Lindhe[9] published an animal study and proposed that soft tissue around dental implants required a certain thickness to form biological structures similar to biological width around teeth. Suárez-López Del Amo et al.[10] evaluated and meta-analyzed five short-term (12 months) studies about the thickness of soft tissue around implants. This study demonstrated that initially thicker soft tissue (>2 mm) around implants favored the formation of biologic width and reduced the amount of crestal bone loss in the short term. Recently, a certain number of clinical studies investigated about the influence of soft tissue thickness on tissue integration of implants. However, studies evaluating the influence of soft tissue thickness on long-term survival of implants and health of peri-implant tissue are rare.

Finding from animal studies of Jeong et al.[11] indicated that after a healing period of 6 months, the length of junctional epithelium and the zone of connective tissue integration around implants were significantly greater in the thick mucosa (6-8 mm) group. Although bone loss did not occur, the authors suspected whether thick mucosa can influence long-term health of peri-implant tissue and become a source of peri-implantitis.

In a 1-year follow-up study, Piao et al.[12] found that peri-implant probing depth and bone loss around 41 subcrestal implants were related to the vertical soft tissue thickness. The thicker the soft tissue thickness, the deeper the peri-implant probing depth was detected, and the more the bone loss was found. It is worth noting that all patients in this study had a history of periodontitis. The authors considered that patients with a history of periodontitis may have relatively thicker soft tissue around implants, which may have an adverse influence on long-term survival rate of implants and health of peri-implant tissue.

Periodontitis was a common disease in Chinese population, and more and more Chinese patients with teeth loss due to periodontitis chose oral rehabilitation with dental implants. Therefore, investigating the mechanism of association between history of periodontitis and the occurrence of peri-implantitis is beneficial to assess the long-term prognosis of implants in patients with a history of periodontitis and carry out necessary interventions avoiding peri-implant disease. The aim of this prospective cohort study was to evaluate the influence of vertical soft tissue thickness on clinical outcome of implant therapy in Chinese patients with a history of periodontitis. The hypothesis is that

implant with thicker vertical soft tissue has higher risk of peri-implantitis.

2 | MATERIALS AND METHODS

2.1 | Patient selection

Patients for this prospective cohort study were recruited from Department of Periodontology, Peking University, School and Hospital of Stomatology. From 2010 to 2015, a total of 210 consecutive patients with partially edentulous who came to the department due to periodontitis and showed initial interest of implant therapy were enrolled. After periodontal treatment, 92 patients were eligible for inclusion. All implant therapies were carried out by an experienced periodontist. The inclusion criteria were: patients with a history of chronic or aggressive periodontitis, and periodontitis was controlled by periodontal system treatment before implant placement; implant restoration with Straumann or Bicon implants, and implant surgery was carried out during 2010 to 2015; complete periodontal record. Exclusion criteria were: systemic disease affecting implant restoration; bad oral habits (bruxism, etc.); and patients during pregnancy or lactation.

Of the 92 patients who met the inclusion criteria, 65 patients (70.7%) eventually participated the follow-up evaluation during 2018 to 2019. Three patients (3.3%) were unable to get in touch; 24 patients (26.0%) refused to participate because of various reasons such as busy work (Figure 1).

Each patient received verbal and written instructions and signed the informed consent form, giving permission to use data obtained for research purposes. The study protocol was approved by the Ethics Committee of the Peking University Health and Science Center (approval number: IRB00001052-10047).

2.2 | Periodontal therapy

After supragingival scaling, all included patients received periodontal assessment in detail. All patients were diagnosed as varying degrees of periodontitis and received nonsurgical treatment (scaling + root planning) as well as necessary surgical periodontal therapy. Prior to the implant therapy, all patients had proceeded to the maintenance phase of treatment.

2.3 | Implant therapy

Either Straumann (bone level or tissue level type) or Bicon (subcrestal type) implants were chosen for implant therapy. Implant sites and surgical procedures were in accordance with the manufacturer's recommended indications and protocols. Conventional implantation was chosen for the timing of most of implant placement, only small number of implants chose immediately implantation. After implant surgery, all patients received antibiotics for 1 week. Amoxicillin was preferred, if patient was allergic to penicillin, took azithromycin. All patients were partially dentate, so fixed prosthesis including single crown, combined crown, and fixed partial dentures were used. The timing of implant loading was 3 to 6 months after placement.

2.4 | Baseline (T1) measurements

The patient's general health status, smoking status, and periodontal charts before implant therapy were collected at baseline. The full-mouth clinical probing depth (PD), bleeding index (BI; Mazza et al. 1981),[13] tooth mobility, gingival recession of patients were recorded in the periodontal charts at baseline and follow-up evaluation.

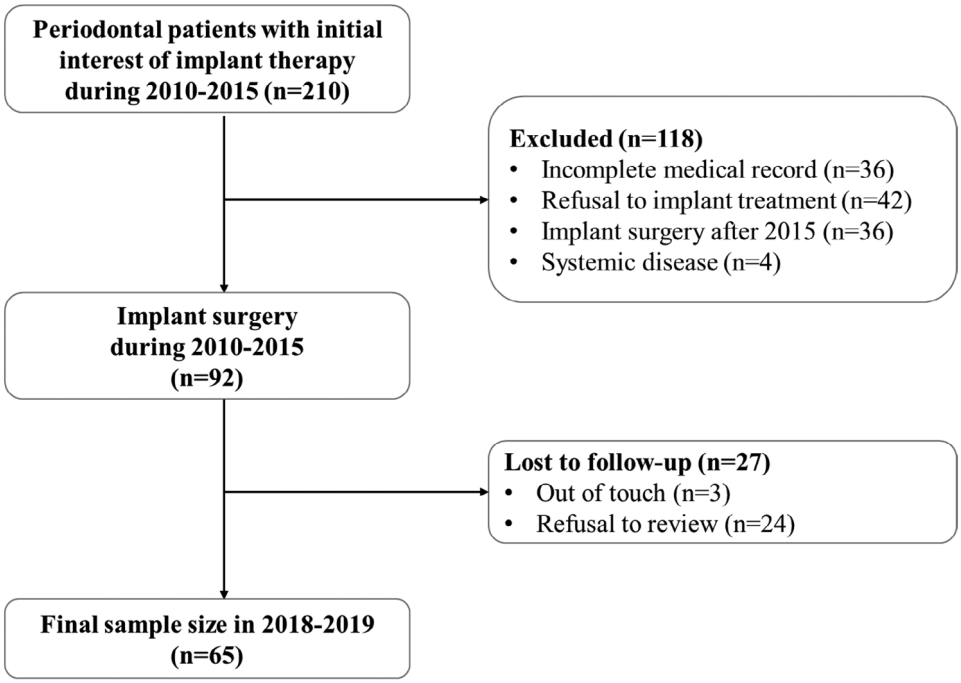

FIGURE 1 Participants selection flowchart

Patients were defined as current smokers if they smoked at the time of baseline measurement. According to the study of Cho-Yan Lee,[14] the definition of residual pockets was PD≥6 mm, and the percentage of residual pockets per patient (residual PD%) was calculated. During the implant placement, the distance from palatal/lingual soft tissue edge to the alveolar crest, which was defined as vertical soft tissue thickness, was measured after the buccal full thickness flap elevated. In addition, imaging data after implants placement and after implants loading was also included in the database.

2.5 | Follow-up (T2) evaluation

During 2018 to 2019, patients were re-called for follow-up (T2) examination. In the T2 examination, implant-related clinical parameters were recorded, including:

- Implant survive/loss.
- Peri-implant probing depth (PDi), including mean of each implants (mean PDi) at six sites (mesiobuccal, buccal, distobuccal, distolingual, lingual, and mesiolingual), and the deepest PD of each implants (max PDi).
- Peri-implant bleeding index (BIi), using Mazza Bleeding Index (Mazza et al., 1981; including six grades from 0 to 5), also including the mean BIi and the max BIi.
- Peri-implant plaque index (PLIi), which was recorded as proposed by Mombelli et al. (1987)[15] and scored at two sites for each implant (buccal and lingual/palatal).

In addition, considering the frequency of patients' periodontal maintenance in current study was general low, the patient maintenance status was divided into two categories, no maintenance (M0): no maintenance during the follow-up period; maintenance (M1): the number of maintenances during the follow-up period ≥1.

Standardized intra-oral periapical radiographs of all implants were taken at the T2 examination for comparison with radiographs taken after implants loading. The distances between the implant shoulder and the first bone to implant contact (DIB) on the mesial and distal sides of each implant were measured (Figure 2). The diameter of the implant shoulder was used as the known data to calculate the actual DIB after loading (DIB1) and at T2 phase (DIB2) in order to compensate for the enlargement and deformation of the anatomical structure in the X-ray. The marginal bone loss (MBL) around implants was defined as difference between DIB1 and DIB2, including the mean of each implants (mean MBL), the mean of distal sides (mean MBLd) as well as mesial sides (mean MBLm). All radiographic measurements were conducted at two different time points (≥2 months interval) by a single examiner and mean of measurements at two time points was calculated. The intraclass correlation coefficient was 0.81, so the intra-observer test-retest reliability was acceptable.

The diagnosis of peri-implant disease in current study referenced the report of The 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. The peri-implant mucositis in current study was defined as: BI ≥ 3; MBL < 1 mm; The peri-implantitis in current study was defined as: PDi ≥ 6 mm; BI ≥ 3; MBL ≥ 1 mm.

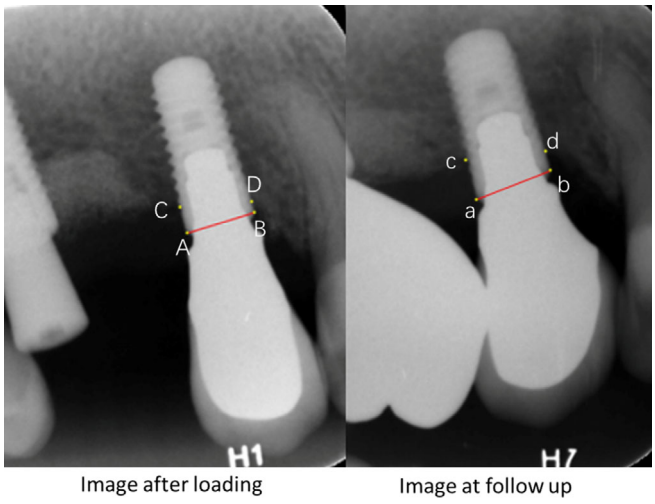

FIGURE 2 Photographic measuring method of margin bone loss (MBL). A-B/a-b: the diameter of implant shoulder; C-D/c-d: the first bone-to-implant contact; C-A, D-B/c-a, d-b: the distance between the implant shoulder and the first bone to implant contact (DIB) on the mesial and distal sides

2.6 | Statistical analysis

All analyses were performed using Empower(R) (www.empowerstats.com, X&Y solutions, Inc., Boston, Massachusetts) and R (http://www.R-project.org).

Survival rate of implants and prevalence of peri-implant diseases were calculated. Implants were considered as the unit of analysis. The characteristics of patients and implants were reported. Logistic regression model with generalized estimating equation (GEE) was chosen to conduct univariate and multivariate analysis of the association of peri-implantitis risk with the implant-related and patient-related factors. Four models were used to adjust for the confounders in multivariate analysis. In model 1, the potential risk factors/indicators with substantial evidence (maintenance frequency, smoking, and residual PD%)[16] were adjusted. In model 2, gender, implant sites, design of implant, length, and diameter of implant were selected for adjustment on the basis of a change in effect estimate of more than 10%. In model 3, gender, implant sites, residual PD%, bone grafting, design of implant, maintenance frequency, length, and diameter of implant were adjusted on the basis of a change in effect estimate of more than 10% or their significant association with the risk of peri-implantitis in univariate analysis. In addition to conventional multivariate analysis, a propensity score was calculated for adjustment in model 4. The propensity score was derived using a logistic regression model with generalized estimating equation which included all potential risk factors of peri-implantitis in univariate analysis. Linear regression model was

TABLE 1 The characteristics of patients

Variables	SD/N (%)
N	65
Age (year)	50.9 ± 10.6
Gender	
Male	28 (43.1%)
Female	37 (56.9%)
Current smoking	
Yes	11 (16.9%)
No	54 (83.1%)
Periodontitis	
Chronic	56 (86.2%)
Aggressive	9 (13.8%)
Residual PD%	6.1 ± 6.3

Note: Data were presented as mean SD/N (%).
Abbreviation: PD, probing depth.

TABLE 2 The characteristics of implants

Variables	SD/N (%)
N	159
Vertical soft tissue thickness (mm)	3.74 ± 1.50
Jaw	
Maxillary	79 (49.7%)
Mandible	80 (50.3%)
Position	
Anterior	46 (28.9%)
Posterior	113 (71.1%)
Design of implant	
Subcrestal implant	75 (46.5%)
Bone level	43 (27.4%)
Tissue level	41 (26.1%)
Length of implant	
≤8 mm	75 (47.2%)
>8 mm	84 (52.8%)
Diameter of implant	
≤4.1 mm	67 (42.1%)
>4.1 mm	92 (57.9%)
Bone grafting	
Yes	84 (52.83%)
No	75 (47.17%)
Types of prostheses	
Single crown	147 (93.6%)
Combined crown	8 (5.1%)
Fixed partial dentures	2 (1.3%)
Follow-up period (month)	43.1 ± 15.5
Maintenance frequency	
M1	94 (59.1%)
M0	65 (40.9%)

Note: Data were presented as mean SD/N (%).

applied to analyze the association of the soft tissue thickness with peri-implant parameters at T2, including crude analysis as well as adjusted analysis using propensity score. Data of descriptive information was expressed as mean ± SD, or N (%), and data of univariate as well as multivariate analysis was expressed as OR/β with 95% confidence intervals (CI). A P value of <0.05 was considered to indicate a statistically significant difference.

In logistics regression model of peri-implantitis, our samples size provided the power of 0.89 to detect an effective size of odd ratio = 2.5 for the R^2 = 0.14 and 0.15, respectively.

3 | RESULTS

The study recruited 65 patients, including 28 male and 37 female, with a mean age of 50.9 years (SD 10.06, range 22-74 years). Of these, 54 patients (83.1%) were nonsmokers or former smokers, and 11 patients (16.9%) were current smokers. A total of 159 implants (75 Bicon implants, 43 Straumann bone level implants, 41 Straumann tissue level implants) were included, with a mean follow-up period of 43.1 months after implant loading (SD 15.5, range 24-94 months). Thirty-one implants (19.3%) were in function for more than 5 years (60 months) after loading. Implant restoration methods included single crown (93.6%), combined crown (5.1%), and fixed partial dentures (1.3%). Tables 1 and 2 presented the characteristics of patients and implants in detail.

Two implants failed and were removed at T2 phase. The cumulative Implant survival rate was 98.8%. Furthermore, 94(59.9%) and 17(10.8%) implants were diagnosed as peri-implant mucositis and peri-implantitis respectively. Parameters of peri-implant condition were demonstrated in Table 3.

Univariate analysis of association of peri-implantitis risk with implant-related as well as patient-related factors was conducted, and result showed statistically significant association between vertical soft tissue thickness and occurrence of peri-implantitis (OR 2.52; 95% CI: 1.63, 3.90, P < 0.05). Compared with univariate analysis, the association between soft tissue thickness and occurrence of peri-implantitis did not change markedly in multivariate analysis with models 1 to 4 (model 1: OR 2.47, 95% CI: 1.45, 4.22; model 2: OR 2.52, 95% CI: 1.56, 4.09; model 3: OR 2.55, 95% CI: 1.48, 4.40; model 4: OR 2.48, 95% CI: 1.59, 3.88). Details were demonstrated in Tables 4 and 5.

There were significant association between soft tissue thickness and meanPDi, maxPDi, meanBIi, meanMBL, meanMBLm, meanMBLd, and meanPLIi at T2 (P < 0.05, Table 6). Additionally, the association between the soft tissue thickness and maxBIi did not perform significantly.

Moreover, the operating characteristic curve indicated that the ability of vertical soft tissue thickness for prediction of peri-implantitis events has good specificity and sensitivity (area under the curve was 0.818, Figure 3).

TABLE 3 Implant-related variables at T2 phase

Variables	SD/N (%)
Implant success	
Survival	157 (98.7%)
Failure	2 (1.3%)
Peri-implant diseases	
Peri-implant mucositis	94 (59.9%)
Peri-implantitis	17 (10.8%)
Peri-implant health	24 (29.3%)
Peri-implant conditions	
Max PDi(mm)	4.78 ± 1.72
Mean PDi(mm)	3.51 ± 1.42
Max Bli	2.77 ± 1.17
Mean Bli	2.32 ± 1.16
Mean MBLm (mm)	0.56 ± 0.48
Mean MBLd (mm)	0.56 ± 0.56
Mean MBL (mm)	0.57 ± 0.46
Mean PLIi	1.99 ± 0.81

Note: Data were presented as mean SD/N (%).
Abbreviations: BI, bleeding index; Bli, peri-implantal BI; MBL, marginal bone level; PD, probing depth; PDi, peri-implantal PD; PLIi, peri-implantal plaque index.

4 | DISCUSSION

The aim of this study was to evaluate the influence of vertical soft tissue thickness on the peri-implant condition and occurrence of peri-implantitis in patients with a history of periodontitis. The result demonstrated that vertical soft tissue thickness was significantly associated with peri-implant parameter as well as risk of peri-implantitis. Increase of vertical soft tissue thickness was associated with increases of peri-implant probing depth and bone loss, and the risk of peri-implantitis increased 1.5 times for 1 mm increase of soft tissue thickness.

In this study, the measurement method of soft tissue thickness was measuring thickness of the lingual/palatal soft tissue directly with the periodontal probe, which was similar to the measurement method in the study published by Linkevicius et al.[17] This method is more direct visibility than ultrasonic and radiographic methods, and periodontal probe is a reliable tool for measuring periodontal tissue and peri-implant tissue condition.

Recently, numerous studies have demonstrated the effect of soft tissue thickness on tissue integration of implants. Linkevicius et al.[17] published a prospective study which divided implants into thick group(soft tissue thickness >2 mm) and thin group (soft tissue thickness ≤ 2 mm). In thin group, peri-implant bone loss 1 year after implant loading was 1.61 ± 0.24 mm in mesial side, and 1.28 ± 0.167 mm in distal side; in thick group peri-implant bone loss 1 year after implant loading was 0.26 ± 0.08 mm in mesial side, and 0.09 ± 0.05 mm in distal side. This study indicated that thicker soft tissue can reduce amount of per-implant bone loss in the first year after loading ($P < 0.05$). Subsequent studies by the same author have further confirmed that thinner vertical soft tissue around implants no matter with design of bone level or platform switching may result in more bone loss during bone remodeling period. In addition, soft tissue thickening surgery in order to increase vertical soft tissue thickness was proved as an effective method which can reduce bone loss during

TABLE 4 Univariate analysis of association between peri-implantitis risk and the implant-related as well as patient-related factors

	Univariate analysis	
Peri-implantitis	OR 95% CI	*P* value
Soft tissue thickness	2.52 (1.63, 3.90)	<0.0001*
Bone grafting		
No	Reference	
Yes	2.33 (1.01, 5.36)	0.0461*
Follow-up period	1.02 (0.99, 1.04)	0.1409
Type of implant		
Subcrestal implant	Reference	
Bone level	0.73 (0.18, 2.94)	0.6575
Tissue level	0.77 (0.16, 3.66)	0.7414
Length of implant		
≤8 mm	Reference	
>8 mm	0.23 (0.06, 0.87)	0.0309*
Diameter of implant		
≤4.1 mm	Reference	
>4.1 mm	1.04(0.37, 2.92)	0.9398
Position		
Anterior	Reference	
Posterior	0.71 (0.21, 2.40)	0.5796
Jaw		
Maxillary	Reference	
Mandible	0.18 (0.05, 0.64)	0.0079*
Maintenance frequency		
0	Reference	
1	0.33 (0.11, 1.01)	0.0514
Gender		
Female	Reference	
Male	2.21 (0.71, 6.83)	0.1695
Age	1.03 (0.98, 1.08)	0.1888
Current smoking		
No	Reference	
Yes	1.65 (0.49, 5.57)	0.4193
Periodontitis		
Chronic	Reference	
Aggressive	1.55 (0.37, 6.42)	0.5451
Residual PD%	1.03 (1.01, 1.05)	0.0075*

Note: Logistic regression analyses were used with generalized estimating equations (GEE). Data was presented as OR with 95% CI.
Abbreviations: CI, confidence intervals; OR, odds ratio; PD, probing depth.
*P value <0.05.

TABLE 5 Multivariate analysis of association between peri-implantitis and soft tissue thickness

	Model 1		Model 2		Model 3		Model 4	
Peri-implantitis	**OR (95% CI)**	***P* value**	**OR (95% CI)**	***P* value**	**OR (95% CI)**	***P* value**	**OR (95% CI)**	***P* value**
Soft tissue thickness	2.47 (1.45, 4.22)	00009*	2.52 (1.56, 4.09)	0.0002*	2.55 (1.43, 4.40)	0.0007*	2.48 (1.59, 3.88)	<0.0001*

Note: Logistic regression analyses were used with generalized estimating equations (GEE). Data was presented as OR with 95% CI. Adjust for maintenance frequency, smoking and residual PD% in model 1; adjust for gender, jaw, design of implant, length and diameter of implant in model 2; adjust for gender, residual PD%, jaw, bone grafting, design of implant, maintenance frequency, length and diameter of implant in model 3; and adjust for Propensity Score in model 4.

Abbreviations: CI, confidence intervals; OR, odds ratio.

*P value <0.05.

TABLE 6 Multivariate analysis of the association between soft tissue thickness and peri-implant parameter at T2 phase

	Crude 95% CI	*P* value	Adjusted 95% CI	*P* value
Mean PDi	0.46 (0.23, 0.70)	0.0001*	0.44 (0.21, 0.67)	0.0002*
Max PDi	0.50 (0.24, 0.77)	0.0002*	0.47 (0.21, 0.73)	0.0004*
Mean Bli	0.22 (0.03, 0.40)	0.0198*	0.18 (0.00, 0.36)	0.0484*
Max Bli	0.11 (−0.06, 0.28)	0.2200	0.07 (−0.10, 0.24)	0.3931
Mean MBL	0.11 (0.06, 0.15)	<0.0001*	0.11 (0.06, 0.16)	<0.0001 *
Mean MBLm	0.09 (0.04, 0.14)	0.0011*	0.09 (0.03, 0.15)	0.0020*
Mean MBLd	0.13 (0.08, 0.18)	<0.0001*	0.13 (0.08, 0.18)	<0.0001*
Mean PLIi	0.17 (0.09, 0.26)	0.0001*	0.16 (0.08, 0.25)	0.0002*

Note: Linear regressions were used with generalized estimating equations (GEE). Data was presented as β with 95% CI.

Abbreviations: Adjusted, adjustment for propensity score; BI, bleeding index; Bli, peri-implantal BI; CI, confidence intervals; Crude, no adjustment; MBL, marginal bone level; PD, probing depth; PDi, peri-implantal PD; PLIi, peri-implantal plaque index.

*P value <0.05.

bone remodeling period.[18-21] The assumption why thin soft tissue may lead to peri-implant bone loss during bone remodeling period is due to the establishment of the biologic width of implant.[21,22] Previous studies have demonstrated that the biologic width of implant (more than 2 mm) is usually wider than that of the natural tooth, so when the soft tissue thickness around the implant is not sufficient (less than 2 mm), the peri-implant bone loss has higher probability to be occurred during establishing of the biologic width.

Until now, all studies investigating the relationship between vertical soft tissue thickness and peri-implant condition focused on the effect of thin vertical soft tissue on early bone loss, and had short follow-up period (1 year). The aim of current study was to evaluate the influence of vertical soft tissue thickness on health of peri-implant tissue. Previous studies indicated that compared with health peri-implant tissue, peri-implantitis was more frequently associated with pathogenic bacteria of periodontitis (eg, Porphyromonas gingivalis and Tannerella forsythia).[23] Papaioannou et al.[24] performed microbiological analysis of implants in patients with a history of periodontitis and found the close relationship between peri-implant probing depth and the pathogenicity of plaque around the implant. The higher proportion of pathogenic bacteria of periodontitis was strongly linked up to deeper peri-implant PD, usually resulted in the higher risk of peri-implantitis. After observation and analysis of microorganism around implants with 2-year-follow-up period after loading, Yan et al.[25] reported that the implants with deep PD had significantly higher odds rate (peri-implant PD≥4/<4 mm OR 3.94) for colonization of pathogenic bacteria of periodontitis. Considering that initial vertical soft tissue thickness is closely related to the peri-implant sulcus and probing depth around implants, the influence of vertical soft tissue thickness on the peri-implant condition should also be taken into account.

Severe periodontitis is a very common disease, which ranks one of the six diseases with the highest prevalence in the world.[26] Strong evidence from a large number of studies was showed that the history of periodontitis is one of the most important risk factors for peri-implantitis.[6,8,27-31] In addition, compared with Western countries, Chinese patients with periodontitis usually have longer course before treatment, and the destruction of periodontal tissue is heavier. A multi-center clinical study showed that due to the worse initial periodontal status of Chinese patients, the plaque index and bleeding on probing of 95 short implants after 3 years follow-up were higher than those in Western countries under the same inclusion criteria.[32,33] A cross-sectional investigation about Chinese population indicated that 98% to 99% patients suffered from severe periodontitis before visiting the Department of Periodontology.[34] Nowadays, no researches involving the correlation between periodontitis and vertical soft tissue thickness have been published, but excessive initial vertical soft tissue around implants has higher risk of occurrence in patients with a history of periodontitis, based on authors' clinical experience. An assumption is proposed that long-term inflammatory status of soft tissue around teeth with severe periodontitis was occurred in general,

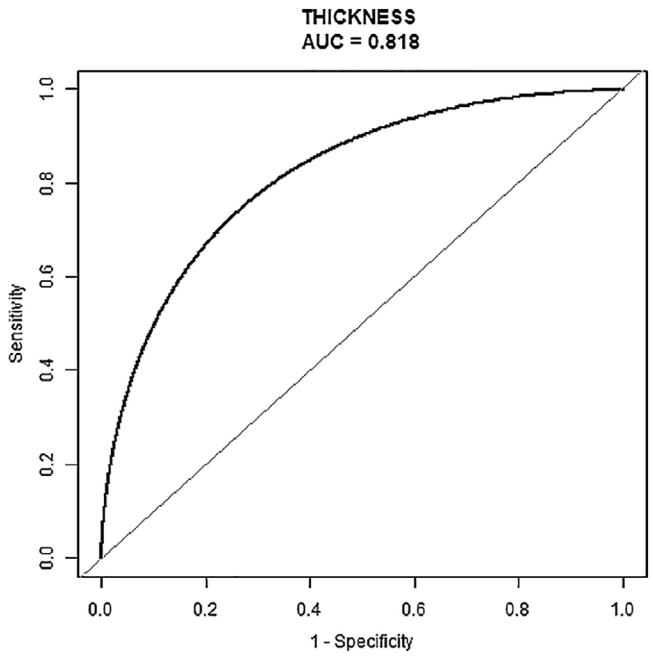

FIGURE 3 ROC curve of soft tissue thickness for prediction of peri-implantitis events. The ability of soft tissue thickness for prediction of peri-implantitis events has good specificity and sensitivity (AUC = 0.818). AUC, area under the curve; ROC, receiver operating characteristic

and usually manifested as deep pocket. After extraction of tooth, inflammatory soft tissue had potential to maintain the volume of deep pocket wall and was remodeled to thicker initial soft tissue compared with health soft tissue. Since the biological width of implant is relatively stable, the deeper peri-implant sulcus may be formed when initial soft tissue was thicker. The periodontal pathogen has higher risk to colonized in deep sulcus around implants, and induces peri-implant bone loss as well as peri-implant diseases.

Results of our study should be interpreted in light of both itsstrengths and limitations. A major limitation is the small number of peri-implantitis events. The small number of events limited the number of confounders adjusted in multivariate analysis, and may cause serious bias of regression coefficients.[35] In order to reduce the impact of this limitation, we conducted multivariate analysis with four models, including adjustment for propensity score. Considering the similar results (OR ≈ 2.5) among univariate and multivariate analysis with four models, the result of the association between soft tissue thickness and risk of peri-implantitis was robust. We will further enlarge the sample size and extend follow-up period in order to confirm the association between soft tissue thickness and peri-implantitis risk found in this study.

In spite of aforementioned limitations, we believe that the significant association between soft tissue thickness and peri-implant condition cannot be fully explained by bias, and the current study has novel implications no matter in theory and in practice. This study is the first study which involved Asian population to evaluate the influence of vertical soft tissue thickness on the peri-implant condition. In current study, excessive vertical soft tissue thickness may result in high risk of peri-implantitis, when patient had a history of periodontitis. This result may indicate a new direction about the association between periodontitis and peri-implant disease. Except for well-known impacts such as microbiology, history of periodontitis may have significant influence on soft tissue morphology (eg, leading to excessive vertical soft tissue thickness), and may final result in unhealthy peri-implant tissue and even occurrence of peri-implantitis.

Further study with longer follow-up period and larger as well as homogeneous sample is needed to investigate the correlation among periodontitis, vertical soft tissue thickness and peri-implant condition. Randomized controlled trial should be designed as far as possible to increase the evidence intensity of research. Moreover, biological mechanism of the association between soft tissue thickness and peri-implantitis risk as well as effective approaches to prevent the adverse effect of excessive soft tissue thickness on peri-implant tissue are necessary to be investigated.

5 | CONCLUSION

According to the results of current study, excessive vertical soft tissue thickness has a significantly adverse effect on the health of peri-implant tissue in the patients with a history of periodontitis. Excessive soft tissue thickness demonstrates significant positive correlation with peri-implant probing depth as well as peri-implant bone loss after average 3 years of function. In addition, when the vertical soft tissue thickness increases 1 mm, the risk of peri-implantitis increases 1.5 times.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

ORCID

Zhong Zhang https://orcid.org/0000-0001-9955-7586
Jie Han https://orcid.org/0000-0001-7229-7964
Wenjing Li https://orcid.org/0000-0002-9905-3836

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