Association between Periodontal Biotype and Clinical Parameters: A Cross-sectional Study in Patients with Skeletal Class III Malocclusion

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Objective: *To evaluate the prevalence of periodontal biotypes in patients with skeletal Class III malocclusion and to explore its association with age, gender, other periodontal clinical parameters and width of keratinized gingiva (WKG).*

Methods: *Data were collected for the buccal-middle site of 310 anterior teeth from 26 subjects who received periodontally accelerated osteogenic orthodontics (PAOO) surgery before orthodontic treatment. Univariate and multivariate analysis were performed to calculate and test the correlations between periodontal biotype and age, gender and bleeding index (BI), gingival recession (GR), plaque index (PLI), probing depth (PD) and WKG.*

Results: *Prevalence of thin periodontal biotype was 33.9% in the anterior region. Mean WKG was 4.37 mm. Univariate analysis showed that a moderately positive correlation was found between WKG and thick biotype ($r = 0.544$, $P < 0.001$). A low positive correlation was detected between mandibular teeth and thick biotype ($r = 0.387$, $P < 0.001$) and a low negative correlation was detected between GR and thick biotype ($r = -0.308$, $P < 0.001$). Multi-level logistic regression showed that biotype was significantly associated with dental arch (odds ratio [OR] = 0.174, $P = 0.015$) and WKG (OR = 2.043, $P = 0.002$). No significant associations were detected between biotype and other factors.*

Conclusion: *Dental arch and WKG were associated with periodontal biotype in patients with skeletal Class III malocclusion.*

Key words: *periodontal biotype, keratinized gingiva, skeletal Class III malocclusion, orthodontic treatment*

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The thickness of the gingiva influences the behaviour of the soft tissue to any physical, chemical or bacterial damage, the outcome of restorative, periodontal and orthodontic treatment and the overall aesthetics of the dentition[1,2]. In addition, differences in the anatomy and blood supply of gingiva with a thin or thick periodontal biotype may also affect the prognosis of a tooth and its response to periodontal treatment[2].

Thin periodontal biotype is one of the risk factors for gingival recession (GR), especially during orthodontic treatment[3,4]. A retrospective study of the prevalence and severity of GR in mandibular incisors during orthodontic treatment showed that a thin periodontal biotype before treatment was an important predictor of GR[5]. Some scholars also believe that gingiva with thin biotype may be more susceptible to plaque, and result in soft tissue defects[6].

A study of the prevalence of different gingival biotypes in patients with different Angle classifications of malocclusion showed over 53% of maxillary central incisors of patients with Class III malocclusion present

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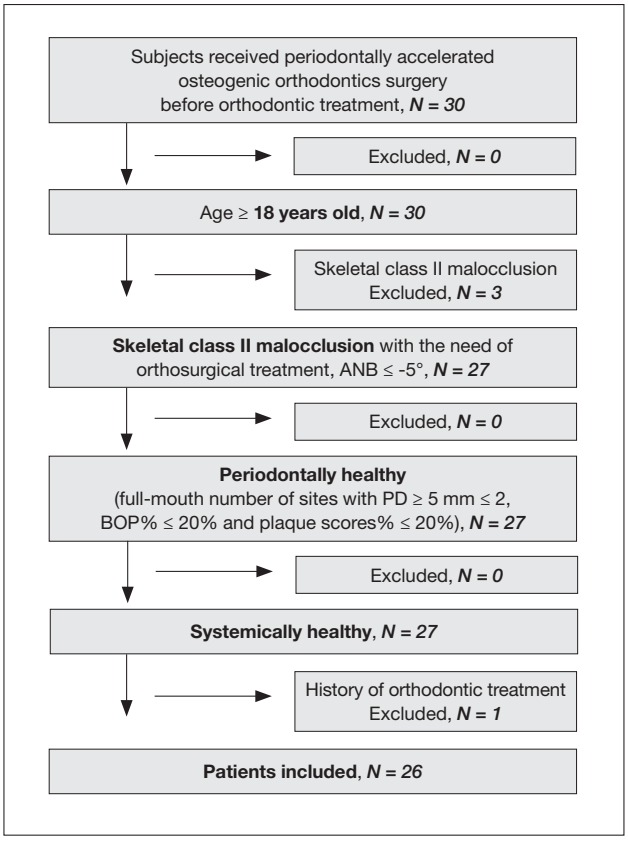

Fig 1 Flowchart showing patient selection and screening.

thin gingival biotype[7]. In addition, dental compensations are often present in patients with skeletal Class III malocclusion, which is manifested by the lingual inclination of the mandibular incisors and the labial inclination of the maxillary incisors to establish a relatively normal incisor coverage and mask the dentofacial deformity. Preoperative orthodontic decompensation is often needed to correct the interference of anterior teeth, which consists of proclining the mandibular incisors and retroclining the maxillary incisors[8]. However, teeth with thin biotype may have a higher risk of GR than those with thick biotype during labial tilting of the anterior teeth[9]. Therefore, a thorough evaluation of periodontal biotype and its influencing factors is particularly important for orthodontic patients with skeletal Class III malocclusion. The aim of the present cross-sectional study was to evaluate the prevalence of periodontal biotypes in patients with skeletal Class III malocclusion and explore its association with age, gender, other periodontal clinical parameters and width of keratinized gingiva (WKG). The hypothesis was that periodontal biotype is associated with these factors.

Materials and methods

The study commenced after obtaining the approval of the Research Ethics Committee of Peking University Health Science Center (approval number: PKUSSIRB-2012052). All protocols were performed in accordance with approved guidelines and regulations, and informed consent was obtained from all participants.

Study population

Subjects who received periodontally accelerated osteogenic orthodontics (PAOO) surgery before orthodontic treatment at the clinic of the Periodontology Department, Peking University School and Hospital of Stomatology from December 2016 to October 2017 were enrolled in the present study.

Inclusion criteria were as follows:
- Age ≥ 18 years old;
- Skeletal Class III malocclusion with the need of orthosurgical treatment, ANB ≤ -5 degrees;
- Periodontally healthy: in full mouth, not more than two sites with probing depth (PD) ≥ 5 mm, bleeding on probing (BOP) ≤ 20%, plaque score ≤ 30%;
- Systemically healthy.

Exclusion criteria were as follows:
- Uncontrolled periodontal infection;
- History of orthodontic treatment or periodontal surgical treatment in anterior teeth;
- Systemic disease (e.g. diabetes mellitus, nephrosis, hepatopathy, hypertension, neutropenia), pregnancy, smoking, or taking medication known to affect periodontal status;
- Cleft lip and palate or maxillofacial abnormalities.
- The process of patient selection and screening is presented in Figure 1.

Data extraction

The following parameters, measured with a Williams periodontal probe with notches located at 1 to 10 mm, were measured at the buccal-middle site of anterior teeth and extracted for analysis: a) Periodontal biotype categorised into thick or thin based on the transparency of the same periodontal probe through the gingival margin while probing the sulcus at the midfacial aspect of the tooth – if the outline of the underlying periodontal probe could be seen through the gingiva, it was categorised as thin; if not, it was categorised as thick (Fig 2)[10]; b) Plaque index (PLI) 0 to 3[11]; c) PD measured (in mm) as

the distance between the gingival margin and the base of the sulcus or pocket at the midfacial aspect of the tooth; d) GR measured (in mm) as the distance between the cementoenamel junction and gingival margin at the midfacial aspect of the tooth; e) Bleeding index (BI) of 0 to 5[12]; f) WKG measured (in mm) as the distance between the mucogingival junction and the gingival margin at the midfacial aspect of the tooth and dental arch (in maxilla vs mandible).

All measurements were performed by a single experienced clinical periodontology professor before PAOO surgery. The calibrations were performed before the examination. Kappa statistics for the intra-examiner agreement for periodontal biotype, PLI and BI ranged from 0.89 to 0.92, and the intraclass correlation coefficient (ICC) for the intra-examiner agreement for measurements of the PD, GR and WKG ranged from 0.92 to 0.98.

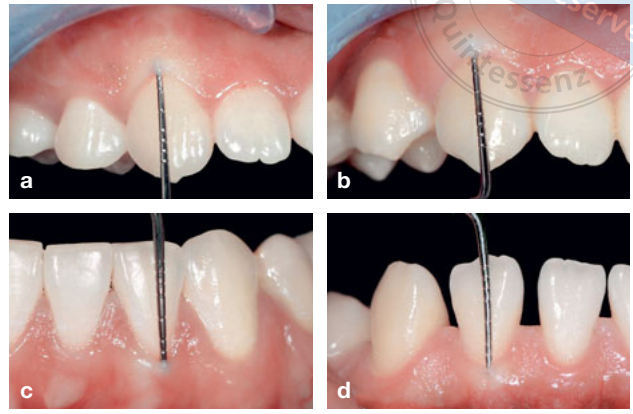

Fig 2 Clinical photographs of teeth with different periodontal biotypes: **(a)** Thin biotype in maxilla. **(b)** Thick biotype in maxilla. **(c)** Thin biotype in mandible. **(d)** Thick biotype in mandible.

Statistical analysis

Firstly, descriptive statistics were performed. Quantitative data were recorded as the mean and standard deviation. Data without Gaussian distribution were evaluated with the Mann-Whitney U test, whereas the Student's t-test or analysis of variance (ANOVA) was used for data with a Gaussian distribution. Categorical data were compared using the chi-square test. Secondly, univariate analysis was performed to calculate and test the correlations between periodontal biotype and age, gender and clinical parameters (Spearman's correlation coefficient for quantitative variables and ordinal variables and contingency coefficient for nominal variables). Thirdly, multivariate analysis based on a three-level (patient at level 1, jaw at level 2 and tooth at level 3) logistic regression was used to explain the hierarchical and clustered structure of the periodontal data. Periodontal biotype (thick vs thin) at the tooth level was the dependent variable of the logistic regression.

Initially, a null model that did not include an independent variable was constructed to investigate the variance of the dependent variables across all levels. The random effects were assumed to follow the Gaussian distribution by the Wald test at all levels. Subsequently, independent variables (age and gender at the patient level, mandible vs maxilla at the jaw level, and PLI [= 3, = 2, = 1, vs = 0], GR, BI [= 4, = 3, = 2, = 1, vs = 0] and WKG at the tooth level) were included in the multilevel regression model to test their association with periodontal biotype. The significances of the independent variables were tested by the Wald test. The regression model was tested for significant improvements in model fit by comparing the reduction in -2LL (-2 log likelihood) with a chi-square distribution. Finally, a sensitivity analysis was performed to assess the robustness of the results. First, a primary multilevel analysis was repeated using data from only the former 19 (75%) subjects who participated in the present study to test the potential effect of the sample size (Model 1). Then, a primary multilevel analysis was repeated when WKG, a quantitative variable, was transformed to a binary data (narrow WKG with a value < 5 mm vs wide WKG with a value ≥ 5 mm) based on the median (5 mm) of WKG (Model 2) to confirm the association between WKG and periodontal biotype. Furthermore, a primary multilevel analysis was also repeated when the dependent variables (tooth, BI and PLI), whose correlations with biotype were insignificant, were excluded from the multilevel analysis (Model 3) and when the dependent variables (age, gender and PD), whose correlations with biotype were few, were further excluded (Model 4). The significance level of all tests was established at $P < 0.05$. Data were evaluated using the IBM SPSS Statistics 19 software package (SPSS; Chicago, IL, USA).

Results

In total, 310 teeth from 26 subjects were included for analysis in the present study. In two patients, a mandibular left lateral incisor and a maxillary left canine were congenitally missing. The demographic characteristics of the subjects and the periodontal parameters

Table 1 Demographic characteristics of subjects and periodontal parameters of included teeth.

		Mean	SD	Min	Max	N	%
Patient level							
Age (years)		23.29	3.71	18.00	34.00		
Gender	Female					17	65.4
	Male					9	34.6
Tooth level							
BI	0					111	35.8
	1					133	42.9
	2					63	20.3
	3					3	1.0
	4					0	0.0
	5					0	0.0
GR (mm)		0.10	0.39	0.00	3.00		
Periodontal biotype	Thin					105	33.9
	Thick					205	66.1
PLI	0					119	38.4
	1					146	47.1
	2					45	14.5
PD (mm)		1.41	0.53	0.00	3.00		
WKG (mm)		4.37	1.75	0.00	8.00		

SD = standard deviation; CI confidence interval = 95%; BI = bleeding index; GR = gingival recession; PD = probing depth; PLI = plaque index; WKG = width of keratinized gingiva.

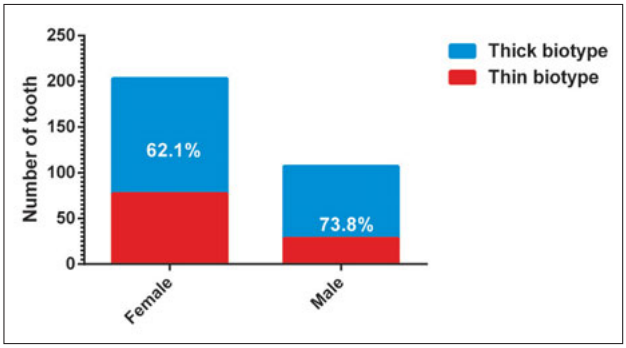

Fig 3 Distribution of periodontal biotype between females and males. Significant difference was detected by the chi-square test ($P = 0.037$).

of the included teeth are shown in Table 1. The mean age of the patients was 23.29, and 65.4% subjects were female. Regarding tooth level, 33.9% of teeth were of a thin periodontal biotype. Mean PD, GR and WKG were 1.41 mm, 0.10 mm and 4.37 mm, respectively. Mean WKG of maxillary teeth was 5.34 mm, and mean WKG of mandibular teeth was 3.39 mm. Proportions of PLI = 0, 1 and 2 were 38.4%, 47.1% and 14.5%, respectively, and proportions of BI = 0, 1, 2 and 3 were 35.8%, 42.9%, 20.3% and 1.0%, respectively.

The distribution of periodontal biotype between females and males is shown in Figure 3. A significantly higher proportion of teeth with a thick biotype was detected in the males (73.8% vs 62.1%, $P = 0.037$). The distribution of periodontal biotype among different teeth

and between maxillary and mandibular teeth is shown in Figure 4a. Comparisons of WKG by tooth and dental arch are shown in Figure 4b. A significantly higher proportion of teeth with thin biotype was detected in the mandible ($P < 0.001$). However, no significant difference in distribution of periodontal biotype was detected among different teeth ($P = 0.281$). The average WKG of central incisors, lateral incisors and canines were 5.55 mm, 5.59 mm and 4.88 mm for maxillary teeth, respectively, and 3.49 mm, 3.68 mm and 3.02 mm for mandibular teeth, respectively. Significantly less WKG was detected in mandibular teeth and canines. A comparison of periodontal parameters between teeth with thin and thick periodontal biotype is shown in Figure 5. The distribution of PLI ($P = 0.050$) and BI ($P = 0.467$) were insignificant. However, significantly more PD (1.48 mm vs 1.28 mm, $P = 0.001$) and WKG (5.06 mm vs 3.02 mm, $P < 0.001$) and less recession (0.01 mm vs 0.26 mm, $P < 0.001$) were detected in teeth with thick biotype.

Correlations between age, gender and clinical parameters with periodontal biotype are shown in Table 2. The results showed that a moderately positive correlation was found between WKG and thick biotype ($r = 0.544$, $P < 0.001$). A low positive correlation was detected between mandibular teeth and thick biotype ($r = 0.387$, $P < 0.001$) and a low negative correlation was detected between GR and thick biotype ($r = -0.308$, $P < 0.001$). Age and PD had few correlations with biotype although their correlation coefficients were significant.

In order to explore the association between clinical periodontal parameters and periodontal biotype, a multilevel logistic regression was performed. The null model with no independent variable included showed that significant variations existed at all levels (all $P < 0.05$). Then, 13 independent variables were included in the multilevel logistic regression. The model based on their odds ratio (OR) and 95% confidence interval (CI) is shown in Table 3. Results from the multilevel analysis showed that the probability of thick biotype was significantly lower in the mandible than in the maxilla (jaw level, OR = 0.174) and the probability would become twice as much when WKG increased by 1 mm (tooth level, OR = 2.043). However, no significant associations were detected between age, gender, tooth, BI, GR, PD and PLI. Furthermore, the addition of the above independent variables significantly improved the fit of the model ($P < 0.05$). A sensitivity analysis showed the results of repeated models to be consistent with the primary one (Table 4, Fig 6) and proved the robustness of the results from the multilevel logistic regression of the present study.

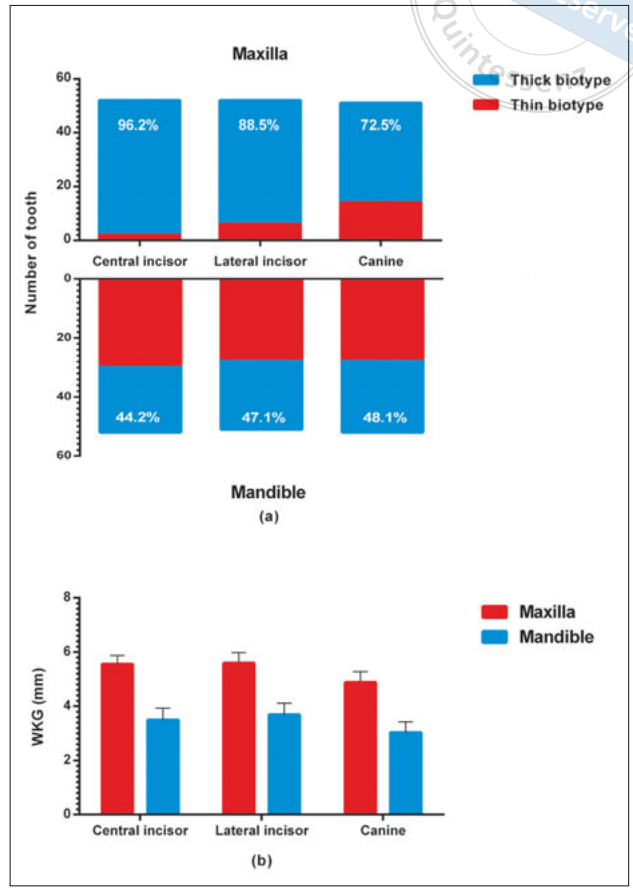

Fig 4 **(a)** Distribution of periodontal biotype among different teeth and between maxillary and mandibular teeth. A significant difference between maxillary and mandibular teeth was detected ($P < 0.001$) and no significant difference among different teeth was detected ($P = 0.281$) by the chi-square test. **(b)** Means and 95% CIs of WKG by tooth and dental arch. Significant differences of WKG tested by two-way ANOVA between mandibular and maxillary teeth and among central incisor, lateral incisor and canine were detected ($P < 0.001$ and $P = 0.001$, respectively). Post hoc analysis showed that significant differences of WKG were detected between canine and central incisor, and between canine and lateral incisor. However, the difference of WKG between central incisor and lateral incisor was insignificant.

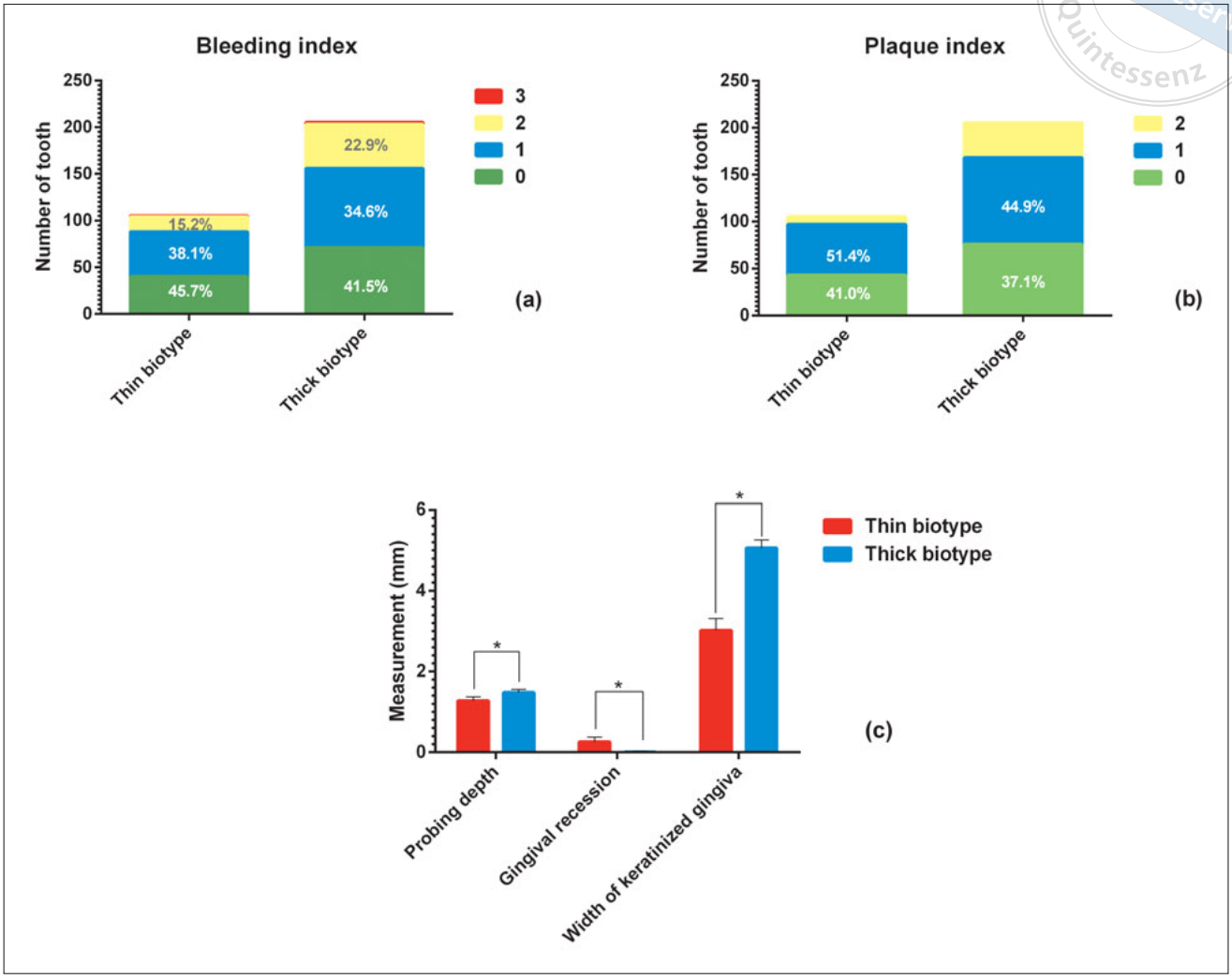

Fig 5 Comparisons of periodontal parameters between teeth with thin and thick periodontal biotype. **(a and b)**: Distributions of PLI ($P = 0.050$) and BI ($P = 0.467$) were insignificant according to the chi-square test. **(c)** Means and CIs are shown. Significant difference of PD ($P = 0.001$), GR ($P < 0.001$) and WKG ($P < 0.001$) were detected by the Student's t-test.

Discussion

Periodontal biotype plays a significant role in the development of mucogingival problems and in the success of treatment for recession[13] and wound healing[14], especially for patients during orthodontic treatment. Sites with thin biotype are more vulnerable to tissue damage and loss; thus, special atraumatic treatment and oral hygiene are needed[2].

A study including 60 mandibular incisors reported that a higher risk of GR was found in teeth with thin periodontal biotype[15]. A study evaluated the influence of periodontal biotype on the outcome of localised Miller Class I or II GRs by the subepithelial connective tissue graft plus the coronally advanced flap technique[16]. Results from the study showed that the percentage of root coverage of teeth with thin biotype was significantly lower than that for teeth with thick biotype. Therefore, discreet consideration and assessment of the periodontal biotype is essential for treatment planning, particularly in patients with skeletal Class III malocclusion because their anterior teeth have a higher prevalence of thin biotype[17].

Previous studies have reported differences in the gingival thickness of the maxillary and mandibular teeth. A study to evaluate the facial gingival profiles of teeth with a healthy periodontium in an Asian population showed that gingival width was greater for maxillary than for mandibular teeth, assessed by both transgingival probing and probe visibility through the marginal gingiva[18].

Table 2 Correlations between age, gender and clinical parameters with periodontal biotype (thick vs thin).

	Correlation coefficient	*P*
Patient level		
Age (years)	0.127*	0.026
Gender (male vs female)	0.180**	0.002
Jaw level		
Dental arch (mandible vs maxilla)	0.387**	0.000
Tooth level		
Tooth (canine, lateral incisor vs central incisor)	0.067**	0.499
BI (0–5)	0.089*	0.240
GR (mm)	-0.308*	0.000
PD (mm)	0.177*	0.002
PLI (0–3)	0.087*	0.125
WKG (mm)	0.544*	0.000

SD = standard deviation; 95% confidence interval (CI) = 95%; BI = bleeding index; GR = gingival recession; PD = probing depth; PLI = plaque index; WKG = width of keratinized gingiva; * Spearman's correlation coefficient; ** contingency coefficient; significant independent variables shown in bold.

Table 3 Association by multilevel logistic regressions between clinical periodontal parameters and periodontal biotypes (thick vs thin).

	Odds ratio	95% CI	*P*
Intercept	0.008	(0.001, 2.299)	0.094
Patient level			
Age (years)	1.152	(0.914, 1.450)	0.229
Male (vs female)	2.287	(0.382, 13.676)	0.363
Jaw level			
Mandible (vs maxilla)	0.174	(0.043, 0.714)	0.015
Tooth level			
Canine	0.554	(0.207, 1.486)	0.240
Lateral incisor	0.659	(0.255, 1.705)	0.389
BI = 3	0.317	(0.009, 11.532)	0.530
BI = 2	2.654	(0.581, 12.116)	0.207
BI = 1	2.66	(0.732, 9.657)	0.137
GR (mm)	0.110	(0.009, 1.38)	0.087
PD (mm)	1.181	(0.422, 3.306)	0.751
PLI = 2	1.339	(0.277, 6.485)	0.716
PLI = 1	0.895	(0.297, 2.701)	0.844
WKG (mm)	2.043	(1.301, 3.206)	0.002

Confidence interval (CI) = 95%; BI = bleeding index; GR = gingival recession; PD = probing depth; PLI = plaque index; WKG = width of keratinized gingiva; significant independent variables shown in bold.

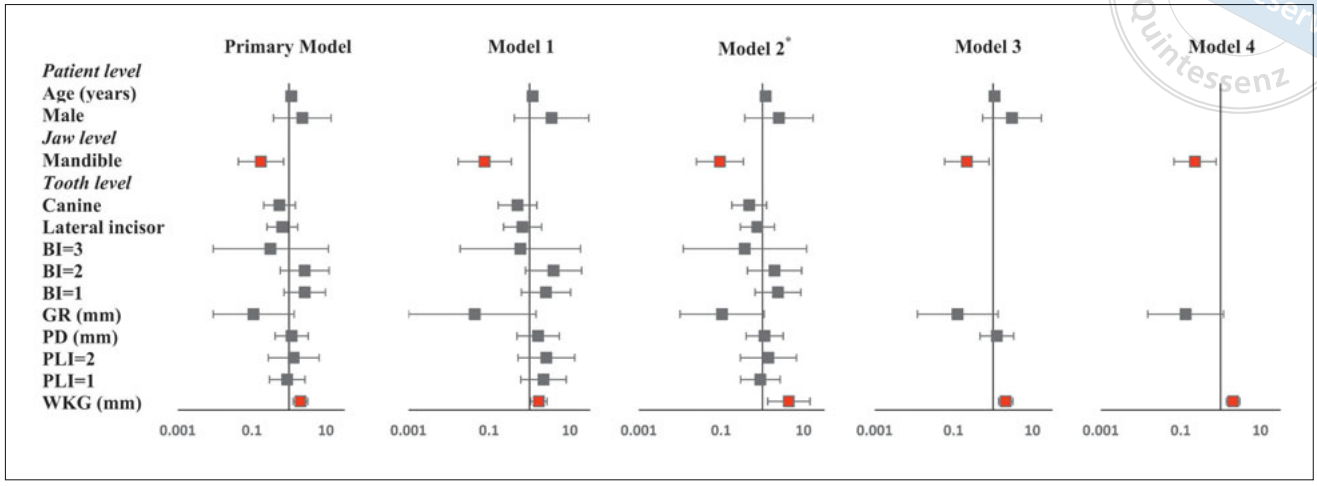

Fig 6 Forest plots of the primary multilevel logistic regression model and repeated models. OR (95% CI). Model 1: the former 19 (75%) subjects who participated in the present study included for analysis; Model 2: WKG was transformed to binary data for analysis; Model 3: dependent variables (tooth, BI and PLI) whose correlations with biotype were insignificant were excluded from the logistic model; Model 4: dependent variables (age, gender and PD) whose correlations with biotype were few were further excluded from the logistic model. * Narrow WKG with a value of < 5 mm vs wide WKG with a value of ≥ 5 mm based on the median (5 mm) of WKG. Significant independent variables are shown in red.

However, another study to evaluate the thickness of the gingiva in Indians and its association with age, gender and dental arch reported that no significant differences were found between gingival thickness of maxillary and mandibular teeth. In contrast, when a subgroup analysis was performed and the gingival thickness of maxillary and mandibular teeth was stratified by age, the gingival thickness of mandibular teeth was less than that of maxillary teeth for both the younger (16 to 24 years) and older (25 to 38 years) age groups[19]. However, the exact opposite result was found when the comparison was made after stratification by gender. Similarly, a study with a similar design and population reported an opposite finding: results from the study showed that the mean width of the attached gingiva of maxillary teeth was greater than that of mandibular teeth in all age groups; however, the value of the maxillary teeth was less than that of the mandibular teeth when subgroup analysis was carried out by gender. Inconsistency among results from various studies may be attributed to bias due to confounding factors such as age and gender as well as racial and genetic factors and also the characteristics of subjects and teeth included for analysis[20].

In the present study, the percentage of teeth with thin biotype was 33.9%, and the percentage of mandibular teeth with thin biotype was significantly higher than that of maxillary teeth (Fig 4a). Furthermore, a multiple regression analysis was also performed to adjust the potential confounding factors, which minimised the bias by age and gender of the subjects included as well as the clinical parameters at tooth level. Results from the logistic regression model showed that a significant association was found between the gingival biotype and the dental arch (Table 3), and the mandibular teeth of subjects with skeletal Class III malocclusion may have a higher risk of mucogingival problems. Therefore, special attention should be paid to teeth with thin biotype, and preventive periodontal surgery such as subepithelial connective tissue grafts may need to be performed in these cases before orthodontic treatment.

Like periodontal biotype, WKG plays an important role in the maintenance of periodontal health during orthodontic treatment[17]. In the present study, WKG in maxillary anterior teeth was significantly greater than in mandibular teeth (Fig 4b). A similar trend was also found in a classic study of the width of attached gingiva carried out more than 50 years ago[21], and a recent study measuring WKG of anterior teeth in 120 healthy Chinese volunteers aged 20 to 30 years[22]. However, the mean WKG of all anterior teeth in the present study was less than those in the two previously cited studies. The difference in WKG may be attributed to the variation of subjects included: only subjects with skeletal Class III malocclusion were included. This supposition was supported by a study that evaluated the relationship of gingival thickness and WKG with different malocclusion groups in an Asian population[17]. Results from this study showed that WKG of mandibular teeth of subjects with

Table 4 Comparison between primary multilevel logistic regression model and repeated models.

	Primary model	Model 1	Model 2	Model 3	Model 4
Patient level					
Age (years)	1.152 (0.914, 1.450)	1.200 (0.896, 1.607)	1.197 (0.938, 1.529)	1.092 (0.880, 1.356)	
Male	2.287 (0.382, 13.676)	3.513 (0.419, 29.434)	2.507 (0.372, 16.905)	2.999 (0.541, 16.62)	
Jaw level					
Mandible	0.174 (0.043, 0.714)	0.077 (0.017, 0.355)	0.093 (0.025, 0.345)	0.217 (0.059, 0.793)	0.229 (0.068, 0.774)
Tooth level					
Canine	0.554 (0.207, 1.486)	0.503 (0.167, 1.512)	0.478 (0.181, 1.259)		
Lateral incisor	0.659 (0.255, 1.705)	0.672 (0.227, 1.989)	0.754 (0.291, 1.956)		
BI = 3	0.317 (0.009, 11.532)	0.592 (0.019, 18.361)	0.372 (0.012, 11.796)		
BI = 2	2.654 (0.581, 12.116)	3.943 (0.792, 19.624)	1.959 (0.431, 8.908)		
BI = 1	2.660 (0.732, 9.657)	2.557 (0.628, 10.399)	2.371 (0.661, 8.509)		
GR (mm)	0.110 (0.009, 1.38)	0.044 (0.001, 1.447)	0.104 (0.010, 1.096)	0.125 (0.012, 1.333)	0.133 (0.015, 1.19)
PD (mm)	1.181 (0.422, 3.306)	1.639 (0.490, 5.482)	1.131 (0.403, 3.176)	1.241 (0.465, 3.314)	
PLI = 2	1.339 (0.277, 6.485)	2.605 (0.516, 13.152)	1.394 (0.291, 6.682)		
PLI = 1	0.895 (0.297, 2.701)	2.215 (0.607, 8.091)	0.890 (0.295, 2.686)		
WKG (mm)	2.043 (1.301, 3.206)	1.699 (1.067, 2.706)	4.359 (1.339, 14.192)*	2.085 (1.378, 3.155)	2.068 (1.398, 3.058)

Odds ratio (95% CI). Model 1: the former 19 (75%) subjects who participated in the present study included for analysis; Model 2: WKG was transformed to a binary data for analysis; Model 3: dependent variables (tooth, BI and PLI) whose correlations with biotype were insignificant were excluded from the logistic model; Model 4: dependent variables (age, gender and PD) whose correlations with biotype were few were further excluded from the logistic model; * narrow WKG with a value of < 5 mm vs wide WKG with a value of ≥ 5 mm based on the median (5 mm) of WKG; significant independent variables shown in bold.

Angle Class III malocclusion was less than those with Angle Class I and II, although a significant difference was not detected. In addition, results from the present study also showed that WKG of canines was less than that of central and lateral incisors, which is similar to the results of the previously cited studies[22,23].

The results of the present study showed that WKG was positively associated with thick biotype ($r = 0.544$, $P < 0.001$), and the probability of thick biotype would double when WKG increased by 1 mm (Table 2). This finding was consistent with several extant studies focusing on the correlation between periodontal biotype and WKG. A study to evaluate the correlation of gingival biotype measured by the probe transparency method with WKG, PD and papillary fill in maxillary anterior teeth in dental students reported that a moderate correlation ($r = 0.555$, $P < 0.001$) was found between WKG and periodontal biotype[24]. Similar results were also reported in a study with a similar study design and way of classifying periodontal biotype, and a weaker correlation ($r = 0.241$, $P < 0.001$) was found between WKG and periodontal biotype[15]. In another study, the gingival thickness at different apicocoronal levels was measured using a radiographic method[25]. The result of the study showed that correlations between WKG and gingival thickness at all levels were significant, and ranged from 0.17 to 0.27 except for the one at the coronal margin. In addition, in other previous studies, gingival thickness was also measured directly by transgingival probing with a periodontal probe, endodontic spreader or syringe with a depth marker[2,26,27]. Results from these studies showed that positive but weak correlations between WKG and gingival thickness were found. However, a negative correlation was also detected in a study between WKG and gingival thickness, both in the maxillary and the mandibular arch[28].

It should be noted that ways of measuring and classifying gingival thickness may also influence results of the association between WKG and periodontal biotype. For a classification based on the transparency of the periodontal probe, two ways of classification were used: binary vs trinary. In addition, for the classification of gingival biotype based on the direct measurement of gingival thickness, different cut-offs were also utilised: 1 mm, 1.5 mm or 2 mm. Therefore, various ways of classifying periodontal biotype may make it difficult to compare studies and also give rise to inconsistency among studies. However, relationship trends between WKG and biotype were similar despite the different periodontal biotype classifications used.

The results of the present and other previous studies showed that thin biotype may accompany an inadequate WKG. Therefore, considering the role of keratinized gingiva in periodontal health and the relationship between WKG and periodontal biotype, the findings further support the importance of more careful treatment planning in patients with teeth with thinner biotype[29].

Multivariate analysis in the present study showed that the association between GR and biotype was insignificant (Table 3) although univariate analysis showed that GR was negatively correlated with gingival biotype (Table 2). This result is also supported by a previous study[2]. Similarly, other clinical parameters such as BI, PLI and PD were also not associated with periodontal biotype (Table 3). However, it should be noted that all subjects included in the present study were periodontally healthy, and differences of periodontal parameters were small. The similarity in periodontal parameters may affect the correlation between biotype and these parameters, and one should be careful not to generalise these results to all periodontally compromised subjects. In addition, further research with a larger sample size and including more potential confounding factors is needed to test the effect of these factors.

The following important limitations of the present explorative study should be noted. Firstly, the sample size was small (26 subjects and 310 teeth) and may have limited the statistical power of the study to some extent. For this reason, a power simulation model was used to evaluate the power of a different sample size, and the results from the power simulation showed that the sample size of the present study should be sufficient to draw a conclusion. Secondly, the specificity of the patients included may affect the generalisability of the result: all the patients included in the present study suffered from skeletal Class III malocclusion, and it is unknown whether these results would be applicable to patients with other forms of malocclusion as well as periodontally healthy patients.

Conclusion

Dental arch and WKG are associated with periodontal biotype in patients with skeletal Class III malocclusion. Further research is needed to replicate these findings in other populations.

Conflicts of interest

The authors reported no conflicts of interest related to this study.

Author contribution

Dr Wu Di JING designed the study, collected and analysed the data and prepared the manuscript; Drs Xiao XU and Jian Xia HOU collected the data; Drs Li XU and Xiao Tong LI critically revised the manuscript.

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References

1. Esfahrood ZR, Kadkhodazadeh M, Talebi Ardakani MR. Gingival biotype: a review. Gen Dent 2013;61:14–17.
2. Shah R, Sowmya NK, Mehta DS. Prevalence of gingival biotype and its relationship to clinical parameters. Contemp Clin Dent 2015;6: S167–S171.
3. Zawawi KH, Al-Zahrani MS. Gingival biotype in relation to incisors' inclination and position. Saudi Med J 2014;35:1378–1383.
4. Rasperini G, Acunzo R, Cannalire P, Farronato G. Influence of Periodontal Biotype on Root Surface Exposure During Orthodontic Treatment: A Preliminary Study. Int J Periodontics Restorative Dent 2015;35:665–675.
5. Melsen B, Allais D. Factors of importance for the development of dehiscences during labial movement of mandibular incisors: a retrospective study of adult orthodontic patients. Am J Orthod Dentofacial Orthop 2005;127:552–561.
6. Wennström JL. The significance of the width and thickness of the gingiva in orthodontic treatment. Dtsch Zahnarztl Z 1990;45:136–141.
7. Zawawi KH, Al-Harthi SM, Al-Zahrani MS. Prevalence of gingival biotype and its relationship to dental malocclusion. Saudi Med J 2012;33:671–675.
8. Pereira-Stabile CL, Ochs MW, de Moraes M, Moreira RW. Preoperative incisor inclination in patients with Class III dentofacial deformities treated with orthognathic surgery. Br J Oral Maxillofac Surg 2012;50:533–536.
9. Gorbunkova A, Pagni G, Brizhak A, Farronato G, Rasperini G. Impact of Orthodontic Treatment on Periodontal Tissues: A Narrative Review of Multidisciplinary Literature. Int J Dent. 2016;2016:4723589.
10. Kan JY, Rungcharassaeng K, Umezu K, Kois JC. Dimensions of peri-implant mucosa: an evaluation of maxillary anterior single implants in humans. J Periodontol 2003;74:557–562.
11. Löe H, Silness J. Periodontal Disease in Pregnancy I. Prevalence and Severity. Acta Odontol Scand 1963;21:533–551.

12. Mazza JE, Newman MG, Sims TN. Clinical and antimicrobial effect of stannous fluoride on periodontitis. J Clin Periodontol 1981;8: 203–212.
13. Baldi C, Pini-Prato G, Pagliaro U, et al. Coronally advanced flap procedure for root coverage. Is flap thickness a relevant predictor to achieve root coverage? A 19-case series. J Periodontol 1999;70: 1077–1084.
14. Anderegg CR, Metzler DG, Nicoll BK. Gingiva thickness in guided tissue regeneration and associated recession at facial furcation defects. J Periodontol 1995;66:397–402.
15. Singh J, Rathod VJ, Rao PR, Patil AA, Langade DG, Singh RK. Correlation of gingival thickness with gingival width, probing depth, and papillary fill in maxillary anterior teeth in students of a dental college in Navi Mumbai. Contemp Clin Dent 2016;7:535–538.
16. Kahn S, Almeida RA, Dias AT, Rodrigues WJ, Barceleiro MO, Taba M Jr. Clinical Considerations on the Root Coverage of Gingival Recessions in Thin or Thick Biotype. Int J Periodontics Restorative Dent 2016;36:409–415.
17. Kaya Y, Alkan Ö, Keskin S. An evaluation of the gingival biotype and the width of keratinized gingiva in the mandibular anterior region of individuals with different dental malocclusion groups and levels of crowding. Korean J Orthod 2017;47:176–185.
18. Lee WZ, Ong MMA, Yeo AB. Gingival profiles in a select Asian cohort: A pilot study. J Investig Clin Dent. 2018 Feb;9: e12269.
19. Vandana KL, Savitha B. Thickness of gingiva in association with age, gender and dental arch location. J Clin Periodontol 2005;32:828–830.
20. Wara-aswapati N, Pitiphat W, Chandrapho N, Rattanayatikul C, Karimbux N. Thickness of palatal masticatory mucosa associated with age. J Periodontol 2001;72:1407–1412.
21. Bowers GM. A Study of the Width of Attached Gingiva. J Periodontol 1963;34.
22. Zhang YL, Zhang H, Hu WJ, Meng HX. Measurement of width on labial keratinized gingiva of anterior dental arch of 120 Chinese Hannationality youth [in Chinese]. Zhonghua Kou Qiang Yi Xue Za Zhi 2010;45:477–481.
23. Lang NP, Lindhe J. Clinical Periodontology and Implant Dentistry, ed 6. Chichester: John Wiley & Sons Ltd, 2015:569.
24. Fischer KR, Künzlberger A, Donos N, Fickl S, Friedmann A. Gingival biotype revisited-novel classification and assessment tool. Clin Oral Investig 2018;22:443–448.
25. Stein JM, Lintel-Höping N, Hammächer C, Kasaj A, Tamm M, Hanisch O. The gingival biotype: measurement of soft and hard tissue dimensions – a radiographic morphometric study. J Clin Periodontol 2013;40:1132–1139.
26. Olsson M, Lindhe J, Marinello CP. On the relationship between crown form and clinical features of the gingiva in adolescents. J Clin Periodontol 1993;20:570–577.
27. Egreja AM, Kahn S, Barceleiro M, Bittencourt S. Relationship between the width of the zone of keratinized tissue and thickness of gingival tissue in the anterior maxilla. Int J Periodontics Restorative Dent 2012;32:573–579.
28. Kolte R, Kolte A, Mahajan A. Assessment of gingival thickness with regards to age, gender and arch location. J Indian Soc Periodontol 2014;18:478–481.
29. Wennström J, Lindhe J, Nyman S. Role of keratinized gingiva for gingival health. Clinical and histologic study of normal and regenerated gingival tissue in dogs. J Clin Periodontol 1981;8:311–328