Clinical Oral Investigations (2023) 27:3569–3577
https://doi.org/10.1007/s00784-023-04970-y

RESEARCH

Clinical and computed tomographic evaluations of periodontal phenotypes in a Chinese population: a cross-sectional study

Yong Zhang[1] · Fan Chen[2] · Ni Kang[3] · Jinyu Duan[1] · Fei Xue[1] · Yu Cai[3]

Received: 30 December 2022 / Accepted: 19 March 2023 / Published online: 24 March 2023

Abstract

Objectives To investigate the diagnostic value of probe transparency related to gingival thickness (GT) and keratinized gingival width (KGW) at individual and site levels and explore the relationship of buccal bone plate thickness (BT) with GT and KGW.

Materials and methods A total of 1,606 teeth from 167 patients with periodontally healthy maxillary anterior region were included. GT was measured with probe transparency and transgingival probing. KGW was measured directly. BTs were assessed at the level 1 mm apical to the alveolar crest (BT1) and midpoint of the root (BT2) and evaluated at individual and tooth levels along with their mutual associations.

Results The prevalence of thick gingiva was 53% with probe transparency measurement and 51% with transgingival probing. The cutoff gingival thickness was 0.8 mm, which correlated moderately with a Cohen's kappa of 0.386. The mean GT, KGW, and BTs (BT1 and BT2) in the maxillary anterior region were 0.97 ± 0.46, 5.51 ± 1.62, 0.85 ± 0.31, and 0.79 ± 0.32 mm, respectively. GT and KGW correlated mildly ($r = 0.261$), and GT and BTs correlated moderately (BT1: $r = 0.298$; BT2: $r = 0.338$). GT and BTs differed significantly between men and women and among different tooth sites.

Conclusions GT and BTs correlated positively in the maxillary anterior region and varied within and among individuals. Sex was a factor influencing the gingival phenotype and bone morphotype.

Clinical relevance GT measured with transgingival probing, with a cutoff of 0.8 mm, could serve as an objective measure to distinguish different gingival phenotypes.

Keywords Gingival phenotype · Gingival thickness · Buccal bone plate thickness · Probe transparency · Transgingival probing

Yong Zhang and Fan Chen are contributed equally to this work.

✉ Fei Xue
sophia_604@126.com

✉ Yu Cai
jessonjesson@hotmail.com

[1] First Clinical Division, Peking University School and Hospital of Stomatology & National Center for Stomatology & National Clinical Research Center for Oral Diseases & National Engineering Laboratory for Digital and Material Technology of Stomatology & Beijing Key Laboratory of Digital Stomatology, Beijing 100081, People's Republic of China

[2] Department of Stomatology, People's Hospital of Peking University, Beijing 100044, People's Republic of China

[3] Department of Periodontology, Peking University School and Hospital of Stomatology & National Center for Stomatology & National Clinical Research Center for Oral Diseases & National Engineering Laboratory for Digital and Material Technology of Stomatology & Beijing Key Laboratory of Digital Stomatology, No.22 South Avenue Zhongguancun, Beijing 100081, People's Republic of China

Introduction

The periodontal phenotype is determined by the gingival phenotype (GP), including gingival thickness (GT) and keratinized gingival width (KGW), and bone morphotype, including buccal bone plate thickness (BT). It is a major parameter in the diagnosis and prognosis of periodontal conditions [1]. GT plays an important role in various gingival and periodontal therapies, including non-surgical therapy, mucogingival therapy, guided tissue regeneration, restorative therapy, and implant treatment [2]. Periodontitis at sites of thin gingiva (GT < 1.5 mm) show clinical attachment loss (CAL) after non-surgical therapy, whereas that at sites of thick gingiva (GT > 2 mm) show no CAL [3]. Periodontal biotypes are related to buccal gingival recession around teeth and implants, and alveolar bone loss is greater at sites of thin gingiva compared to those of thick gingiva [4, 5].

Different techniques have been used to determine the gingival biotype, including probe transparency [6–8], transgingival probing [9, 10], ultrasonic transducer probing [11], parallel profile radiography [12], and soft-tissue cone-beam computed tomography (CBCT) [13]. Among them, the most objective and repeatable assessment of GT is the direct measurement with transgingival probing [14–16]. For transgingival probing, the cutoff GT is a major factor discriminating the gingival biotype and ranges from 0.8 to 2.0 mm across studies [17–19]. Recently, a cutoff GT of 1.0 mm has been suggested to discriminate between thin and thick gingival biotypes in consensus reports by the American Academy of Periodontology and European Federation of Periodontology [2].

Probe transparency is another commonly used clinical method to assess GT. It is highly reproducible, with 85% agreement between duplicate assessments, and correlates positively with GT [20]. However, Eghbali [21] and Stein [22] reported a limited prognostic value of probe transparency. Furthermore, the subjective nature of assessment limits its clinical application.

The role of BT in determining the gingival phenotype is controversial. Cook et al.'s study [23] suggested that the gingival phenotype is reflected by probe transparency, papillary height, keratinized tissue width, and distance from the cementoenamel junction to the alveolar bone crest. However, Frost et al.'s study [17] showed that the gingival biotype was not associated with BT.

Therefore, the aim of the present study was to evaluate the diagnostic value of probe transparency related to GT and KGW at individual and site levels and explore the relationship of BT with GT and KGW. We hypothesized that GT could serve as an objective measure to distinguish different gingival phenotypes and, in turn, improve the predictability of periodontal treatment outcomes.

Materials and methods

Study design

This was a cross-sectional study involving patients with a history of implant treatment, tooth extraction or periodontal treatment in the maxillary posterior or mandibular region. The Institutional Review Board of the Peking University School and Hospital of Stomatology approved the study protocol (approval number: PKUSSIRB-201626022). The study procedures followed the tenets of the 2013 revision of the 1975 Declaration of Helsinki. All participants were explained the study procedures verbally and in writing and provided written informed consent. Primary data were collected according to Strengthening the Reporting of Observational Studies in Epidemiology Statement guidelines.

Patients

We recruited patients who had undergone periodontal examination at the Department of Periodontology, First Clinical Division, Peking University School and Hospital of Stomatology, from January 2017 to December 2019.

Inclusion criteria were: 1) age of 20–65 years; 2) nonsmoker status; 3) no history of systemic diseases; 4) periodontal treatment was done in the maxillary posterior or mandibular region; 5) healthy gingiva in the maxillary anterior region, i.e., no site with a gingival index ≥ 1, probing depth (PD) ≥ 4 mm, or CAL ≥ 1 mm and no radiographic alveolar bone loss; and 6) no crossbite in the anterior teeth or known oral parafunctions.

Exclusion criteria were: 1) crown or implant restorations in the maxillary anterior teeth; 2) a history of periodontal surgery in the maxillary anterior region (flap surgery, guided tissue regeneration, bone grafting, or mucogingival surgery); 3) a history of orthodontic therapy; 4) past or current use of drugs that may cause gingival enlargement; and 5) pregnancy or lactation. All patients received oral hygiene instructions and motivation (Bass toothbrushing technique and use of dental floss and interdental brushes) and underwent supragingival scaling with an ultrasonic scaler and tooth polishing with a rotating rubber cup using a polishing paste 1 week before clinical examination to eradicate any gingival inflammation.

Clinical measurements

The maxillary anterior tooth (central incisors [CIs], lateral incisors [LIs], canines [Cs], and premolars [PMs]) region was examined with a 10-mm manual periodontal probe (PCP10-SE, Hu-Friedy, Chicago, USA), and the measurements were rounded upwards to the nearest mm. Plaque

index, gingival index, bleeding on probing (BOP), PD and CAL were measured at six sites (mesiolabial, midlabial, distolabial, mesiolingual, midlingual, distolingual) of all teeth. BOP was determined when the probed site bled for approximately 20 s after probing.

Probe transparency assessment

Probe transparency was assessed by inserting a periodontal probe (PCP10-SE, Hu-Friedy, Chicago, USA) up to the midpoint of the midfacial gingival sulcus. Y.Z. and F.X. determined the visibility of the probe. The gingiva was considered to be thin when the probe outline could be seen and thick when it could not be seen (Fig. 1A and B).

Direct measurement of GT

GT was directly measured with transgingival probing. The local anesthetic 4% articaine was applied over the region of interest, and measurements were obtained 15 min later. A #15 endodontic K-file (MANI, Tochigi, Japan) was inserted perpendicular to the long axis of the axial plane at the level 1 mm apical to the midfacial gingival margin of the tooth that corresponded to the location of probe transparency assessment (Fig. 1C). The probe tip was inserted through a rubber stopper at a point peripheral to the pre-made hole at the center of the rubber stopper to minimize measurement errors. The probe was inserted until tactile resistance was felt, and the distance between the stopper and the probe tip was measured with a digital caliper with a sensitivity of 0.01 mm.

KGW measurement

At the zenith of the midfacial gingival margin of the tooth that corresponded to the location of probe transparency assessment, KGW was measured as the distance between the free gingival margin and the mucogingival junction using a 10-mm manual periodontal probe (PCP10-SE, Hu-Friedy, Chicago, USA), rounded off to the nearest 0.5 mm.

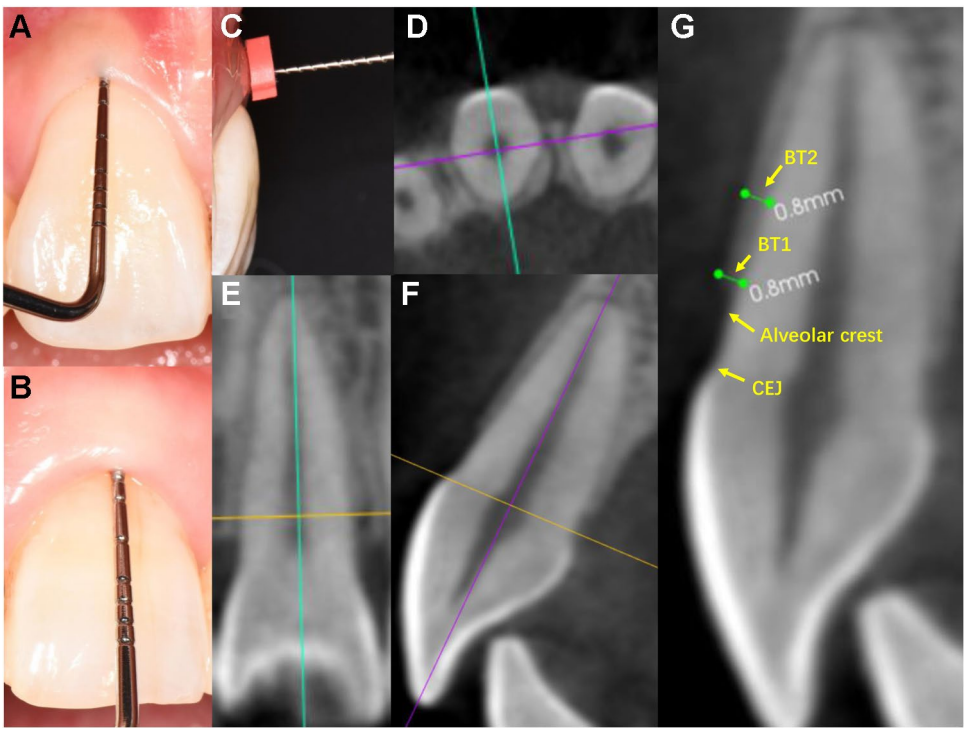

Fig. 1 Clinical and tomographic evaluation of gingival phenotype. **A**) Clinical exam by transparency of the periodontal probe: the probe is visible in the gingival sulcus (thin gingival phenotype). **B**) Clinical exam by transparency of the periodontal probe: the probe is not visible in the gingival sulcus (thick gingival phenotype). **C**) Clinical exam by transgingival probing using endodontic file. **D**) Along the bucco-lingual axis, the sagittal plane was placed in the middle of the selected tooth. **E**) Along the mesio-distal axis, the frontal plane was placed in the middle of the selected tooth. **F**) Along the apico-coronal axis, the axial plane was perpendicular to the long axis of the selected tooth at the level of cemento-enamel junction (CEJ). **G**) Buccal plate thickness was measured from the inner aspect of the buccal plate to the external surface of the buccal plate perpendicular to the long axis of the periodontal ligament space, and measurements were made 1 mm apical to the alveolar crest (BT1) and midpoint of the root (root: from the CEJ to the apex along the long axis of the periodontal ligament space, BT2)

BT measurement

After clinical measurements, BT was measured on CBCT scans, which had been obtained for the patients' comprehensive periodontal or other dental treatment outside of this study. CBCT was performed using Kodak CS 9300 (Carestream Dental LLC, Atlanta, GA, USA) with the following parameters: voltage, 90 kV; current, 10 mA; exposure time, 6.2 s; field of view, 5 × 5 mm; and voxel size, 90 μm. Images were reconstructed, and digital measurements were obtained using CS 3D Imaging Software (Carestream Dental LLC, Atlanta, GA, USA) with an accuracy of 0.01 mm. Images were displayed with the largest possible zoom, appropriate contrast, and brightness on a flat-panel display screen with a resolution of 1920 × 1080 pixels. All scans were aligned in accordance with a protocol for the three dimensions: 1) along the mesiodistal axis, the frontal plane was placed in the middle of the selected tooth; 2) along the buccolingual axis, the sagittal plane was placed in the middle of the selected tooth; and 3) along the apicocoronal axis, the axial plane was perpendicular to the long axis of the selected tooth at the level of the cementoenamel junction. BT was assessed perpendicular to the root surface at the level 1 mm apical to the alveolar crest (BT1) and midpoint of the root (BT2).

Intraexaminer and interexaminer reproducibility controls

Y.Z. and F.C. separately assessed probe transparency, transgingival probing, and KGW measurements. Y.Z. and F.X. separately assessed BT. The accuracy and repeatability of the measurements were repeatedly evaluated in 10 patients at an interval of 2 weeks. The repeatability of measurements was analyzed by Pearson's correlation coefficient or Cohen's kappa. Pearson's correlation coefficients were 0.817 (Y.Z.) and 0.835 (F.C.) for transgingival probing, 0.929 (Y.Z.) and 0.892 (F.C.) for KGW measurement, and 0.822 (Y.Z.) and 0.86 (F.X.) for BT measurement. Cohen's Kappa values were 0.900 (Y.Z.) and 0.900 (F.C.) for probe transparency. The agreements of all measurement between the two examiners were analyzed using intraclass correlation coefficients (ICCs) or Cohen's kappa. ICC was 0.777 (Y.Z. and F.C.) for probe transparency, 0.789 (Y.Z. and F.C.) for KGW measurement, and 0.740 (Y.Z. and F.X.) for BT measurement. Probe transparency showed a combined Cohen's kappa of 0.800 with 90% agreement (Y.Z. and F.C.).

Statistical analysis

G*Power 3.1.9.2 software was used to calculate the sample size, the sample size was calculated by the primary outcome of the agreement between probe transparency and transgingival probing methods. Based on the results from Frost et al.'s study [17], 60%–70% and 30%–40% of teeth were estimated to be classified as thin and thick gingival biotypes, the Cohen's kappa of 0.16 (95%CI: 0.08–0.24) was used to calculate the sample size, considering the minimum acceptable Cohen's kappa of 0.4 to indicate a moderate agreement and an expected Cohen's kappa was to be 0.2 based on the results from Foster et al., a statistical power of 80%, and a significance level of 95% (two-tailed $\alpha = 0.05$). It showed that 120 participants were required to differentiate the gingival biotypes. Therefore, the sample size was determined to be 120 patients.

Statistical analyses were performed using SPSS 21.0 statistical software (SPSS Inc., IBM, Chicago, IL, USA), and data were analyzed using GraphPad Prism V8.0.2 (GraphPad Software, San Diego, CA, USA). Normality of data distribution was tested with the Shapiro–Wilk test. Data are expressed as mean ± standard deviation. Categorical data are expressed as frequency and percentage. Clinical and radiologic parameters, including GT, KGW, and BT, were statistically analyzed using Student's *t*-test and analysis of variance. Agreements in probe transparency, transgingival probing, and KGW measurement between the examiners were analyzed using ICC and Cohen's kappa. Spearman's correlation coefficient was used to analyze the consistency in BT1 and BT2 measurements and correlations of GT, KGW, and BT.

Results

We recruited 1,606 teeth of 167 patients, including 96 men and 71 women, with a mean age of 32.40 ± 8.38 (range: 21–47) years. All the patients were from the Han Chinese ethnic group.

Biotype prevalence

Table 1 shows the distributions of thin and thick gingiva. Based on probe transparency, the overall prevalence of the thick gingival biotype was 52.7%. Sex was associated with the gingival biotype, with men showing a greater prevalence of the thick type compared to women. The prevalence of the thick biotype was 53.7% among CIs, 52.5% among LIs, 49.5% among Cs, and 54.0% among PMs.

When GT measured with transgingival probing was categorized into the thick and thin types with a cutoff of 0.8 mm (thick ≥ 0.8 mm; thin < 0.8 mm), the overall prevalence of the thin and thick biotypes was 49.4% and 50.6%; 67.2% and 32.8% with a cutoff of 1.0 mm respectively, and 84.7% and 15.3% with a cutoff of 1.2 mm respectively. Table 1 shows the distributions of thin and thick gingiva with different cutoff points among different tooth types determined with transgingival probing.

Table 1 Distribution of thick/thin gingiva assessed by different methods and different cutting points

		Tooth type (n)	Thin gingiva		Thick gingiva	
			n	(%)	n	(%)
Probe transparency		Overall (1606)	759	47.3	847	52.7
		Central incisors (320)	148	46.3	172	53.7
		Lateral incisors (320)	152	47.5	168	52.5
		Canines (323)	163	50.5	160	49.5
		Premolars (643)	296	46.0	347	54.0
Transgingival probing	CP 0.8 mm	Overall (1606)	794	49.4	812	50.6
		Central incisors (320)	164	51.2	156	48.8
		Lateral incisors (320)	199	62.2	121	37.8
		Canines (323)	213	65.9	110	34.1
		Premolars (643)	218	33.9	425	66.1 *
	CP 1.0 mm	Overall (1606)	1080	67.2	526	32.8
		Central incisors (320)	221	69.1	99	30.9
		Lateral incisors (320)	251	78.4	69	21.6
		Canines (323)	263	81.4	60	18.6
		Premolars (643)	345	53.7	298	46.3 *
	CP 1.2 mm	Overall (1606)	1360	84.7	246	15.3
		Central incisors (320)	282	88.1	38	11.9
		Lateral incisors (320)	294	91.9	26	8.1
		Canines (323)	303	93.8	20	6.2
		Premolars (643)	481	74.8	162	25.2 *

CP: cutting point

significantly different compared to other tooth group (:$p<0.05$, **:$p<0.01$)

Clinical and radiographic parameters

Table 2 shows the distributions of GT, KGW, BT1, and BT2. The mean GT, KGW, BT1, and BT2 were 0.97, 5.51, 0.85, and 0.79 mm, respectively. Sex and tooth type were associated with GT and BTs, with significant differences between men and women. PMs exhibited the highest GT (1.12 mm) followed by CIs (0.91 mm), LIs (0.83 mm) and Cs (0.79 mm). PMs also showed the highest BTs (BT1: 0.95 mm; BT2: 0.94 mm), followed by CIs (BT1: 0.83 mm; BT2: 0.74 mm), Cs (BT1: 0.80 mm; BT2: 0.72 mm), and LIs (BT1: 0.76 mm; BT2: 0.67 mm). LIs had the highest KGW (5.78 mm), followed by CIs (5.66 mm), Cs (5.52 mm), and PMs (5.33 mm). Table 2 shows the details.

Differences in the gingival biotype measured with probe transparency and transgingival probing

Patients' gingival biotypes were determined with probe transparency and transgingival probing simultaneously. Transgingival probing and probe transparency showed a mild correlation, with a Cohen's kappa of 0.278 ($p<0.01$), when the cutoff GT measured with transgingival probing was set to 1.0 mm; a moderate correlation, with a Cohen's kappa of 0.386 ($p<0.01$), when the cutoff GT was set to 0.8 mm; and a mild correlation, with a Cohen's kappa of 0.226, when the cutoff GT was set to 1.2 mm ($p<0.01$, Table 3).

Differences in gingival biotypes and BTs

Based on probe transparency, the mean GT, KGW, and BTs (BT1 and BT2) were significantly lesser in thin gingiva than in thick gingiva (Table 4).

GT and KGW showed a mild correlation ($r=0.261$, $p<0.01$). BT1 and BT2 showed a strong correlation ($r=0.561$, $p<0.001$). GT and BT1 showed a moderate correlation ($r=0.298$, $p<0.001$). GT and BT2 showed a moderate correlation ($r=0.338$, $p<0.001$). In addition, KGW and BTs (BT1 and BT2) showed no correlation ($p>0.05$, Table 5).

Discussion

The gingival phenotype is a significant factor that may be related to the outcomes and prognosis of periodontal and other dental treatments, particularly in the maxillary anterior region where esthetics is desired. After periodontal therapy, patients with thin gingiva show high risks of gingival recession and alveolar bone loss compared to those with thick gingiva. Furthermore, patients with thick gingiva have more predictable tissue healing after periodontal

Table 2 Descriptive characteristics of clinical and radiographic parameters by different tooth types

	Overall (n = 1606)			Central incisors (n = 320)			Lateral incisors (n = 320)			Canines (n = 323)			Premolars (n = 643)		
	Mean ± SD	Men (n = 908) Mean ± SD	Women (n = 698) Mean ± SD	Mean ± SD	Men (n = 181) Mean ± SD	Women (n = 139) Mean ± SD	Mean ± SD	Men (n = 181) Mean ± SD	Women (n = 139) Mean ± SD	Mean ± SD	Men (n = 184) Mean ± SD	Women (n = 139) Mean ± SD	Mean ± SD	Men (n = 362) Mean ± SD	Women (n = 281) Mean ± SD
GT	0.97 ± 0.46	1.01 ± 0.42	0.92 ± 0.49**	0.91 ± 0.39	0.98 ± 0.45	0.84 ± 0.39**	0.83 ± 0.27#	0.85 ± 0.25	0.80 ± 0.28*	0.79 ± 0.38#	0.81 ± 0.40	0.76 ± 0.34*	1.12 ± 0.48##§§††	1.14 ± 0.48	1.10 ± 0.51
KGW	5.51 ± 1.62	5.57 ± 1.68	5.44 ± 1.57*	5.59 ± 1.56	5.66 ± 1.55	5.52 ± 1.64**	5.78 ± 1.58#	5.85 ± 1.58	5.71 ± 1.63*	5.52 ± 1.53§	5.58 ± 1.47	5.46 ± 1.53**	5.33 ± 1.41#§†	5.36 ± 1.71	5.29 ± 1.47
BT1	0.85 ± 0.31	0.88 ± 0.29	0.82 ± 0.27**	0.83 ± 0.27	0.87 ± 0.29	0.78 ± 0.23**	0.76 ± 0.26#	0.78 ± 0.24	0.73 ± 0.33*	0.80 ± 0.25	0.83 ± 0.34	0.77 ± 0.24*	0.95 ± 0.43#§§ ††	0.97 ± 0.32	0.92 ± 0.22*
BT2	0.79 ± 0.32	0.83 ± 0.27	0.77 ± 0.36**	0.74 ± 0.23	0.77 ± 0.24	0.70 ± 0.29*	0.67 ± 0.25#	0.71 ± 0.24	0.64 ± 0.29*	0.72 ± 0.28§	0.75 ± 0.34	0.69 ± 0.24*	0.94 ± 0.34##§§ ††	0.97 ± 0.45	0.91 ± 0.27*

GT: Gingival thickness; KGW: Keratinized gingival width; BT1: buccal bone plate thickness at the 1 mm apical to the alveolar crest; BT2: buccal bone plate thickness at the midpoint of the root

significantly different compared to males group (: $p < 0.05$, **: $p < 0.01$)

#significantly different compared to central incisors group (#: $p < 0.05$, ##: $p < 0.01$)

§significantly different compared to lateral incisors group (§: $p < 0.05$, §§: $p < 0.01$)

†significantly different compared to canines group (†: $p < 0.05$, ††: $p < 0.01$)

surgery and minimal bone resorption after tooth extraction [1, 24]. Therefore, patients' gingival phenotypes should be assessed to determine the prognosis accurately before treatment. To date, no standardized and reproducible evaluation method has existed.

Probe transparency is the most commonly used clinical method with a reproducible and easy approach. It correlated positively with GT in some studies; however, Lee et al.'s [25] and Shao et al.'s [26] studies concluded no or weak correlation. A recent consensus report has recommended the probe transparency test to assess GT and defined thin gingiva as a GT ≤ 1.0 mm observed as a visible probe [2]. However, in the present study, probe transparency and transgingival probing showed a mild correlation, with a Cohen's kappa of 0.278 when the cutoff GT was set to 1.0 mm; a milder correlation when the cutoff GT was set to 1.2 mm; and a moderate correlation, with a Cohen's kappa of 0.386 when the cutoff GT was set to 0.8 mm. In addition, based on probe transparency, the prevalence of thick gingiva was 52.7% overall, and 50.6%, 32.8%, and 15.3% based on transgingival probing when the cutoff GTs were set to 0.8, 1.0, and 1.2 mm, respectively. The prevalence of thick gingiva based on probe transparency was similar to the prevalence of thick gingiva based on transgingival probing with a cutoff GT of 0.8 mm compared to with cutoff GT of 1.0 or 1.2 mm. These results indicated that the cutoff GT may influence the correlation results. In the present study, the cutoff GT of 0.8 mm was the best choice for probe transparency assessment, consistent with Rodrigues et al.'s [13] study reporting a cutoff GT of 0.8 mm with the measurement representing the best area under the receiver operating characteristic curve (AUC) performance compared to other cutoff GTs and Frost et al.'s [17] study reporting the highest AUC with a cutoff GT of 0.8 mm.

In addition to GT, KGW is a component of the gingival phenotype. In the present study, unlike PMs exhibiting the highest GT, followed by CIs, LIs, and Cs, LIs exhibited the highest KGW, followed by CIs, Cs, and PMs. Similar distributions were reported by Egreja et al. [27] and Shah et al. [28]. Consistent with many studies, the present study showed a moderate positive correlation between KGW and GT in the maxillary anterior region (r = 0.261).

We measured BT at different sites of the alveolar bone (BT1: 1 mm apical to the alveolar crest; BT2: midpoint of the root) and found a strong correlation between BT1 and BT2 (r = 0.561), revealing that the level 1 mm apical to the alveolar crest and midpoint of the root could help evaluate BT and that both BT1 and BT2 had similar distributions as GT across different tooth types. The relationship of BT with GT is controversial. Nikiforidou et al. [18] reported that BT correlated with GT; however, Mallikarjun et al. [29] and Rocca et al. [30] reported no significant correlation. Rocca et al. [30] reported that BT correlated with the attached

Table 3 Association between gingival phenotype evaluated by probe transparency and transgingival probing by different cutting points

			Probe transparency		Chi-square test
			thin	thick	Kappa value
Transgingival probing	CP 0.8 mm	thin	530	264	0.386 **
		thick	229	583	
	CP 1.0 mm	thin	624	456	0.278 **
		thick	135	391	
	CP 1.2 mm	thin	737	623	0.226 **
		thick	22	224	

CP: cutting point

significantly different compared to thin group (:$p<0.05$, **:$p<0.01$)

Table 4 Comparison of clinical and radiographic parameters in thin and thick gingival phenotype evaluated by probe transparency

	Probe transparency	
	Thin (n = 759)	Thick (n = 847)
GT	0.80 ± 0.33	1.12 ± 0.41 **
KGW	5.18 ± 1.51	5.80 ± 1.46 *
BT1	0.80 ± 0.23	0.88 ± 0.26 *
BT2	0.74 ± 0.25	0.81 ± 0.28 *

GT: Gingival thickness; KGW: Keratinized gingival width; BT1: buccal bone plate thickness at the 1 mm apical to the alveolar crest; BT2: buccal bone plate thickness at the midpoint of the root

significantly different compared to thin group (:$p<0.05$, **:$p<0.01$)

Table 5 Correlation analysis of clinical and radiographic parameters

Spearman's rho	GT	KGW	BT1	BT2
GT	1.000	0.261 **	0.298 ***	0.338 ***
KGW	0.261 **	1.000	0.207	0.176
BT1	0.298 ***	0.207	1.000	0.561 ***
BT2	0.338 ***	0.176	0.561 ***	1.000

GT: Gingival thickness; KGW: Keratinized gingival width; BT1: buccal bone plate thickness at the 1 mm apical to the alveolar crest; BT2: buccal bone plate thickness at the midpoint of the root

*statistical significance (**:$p<0.01$, ***:$p<0.001$

gingival width. The present study showed that BTs were not associated with KGW but associated with GT (BT1: r = 0.298; BT2: r = 0.338). Furthermore, BT differed significantly between sites of thick and thin gingiva according to probe transparency (thin gingiva vs. thick gingiva: BT1, 0.80 vs. 0.88 mm; BT2, 0.74 vs. 0.81 mm), consistent with Nikiforidou et al.'s [18] and Cook et al.'s [23] studies. The present results supported the presence of a trend between BT and probe transparency or GT [31].

Race significantly affects the gingival phenotype, with Asians tending to have thinner gingiva compared to Caucasians. In the present study, the average GT in the maxillary anterior region was 0.97 mm, ranging from 0.22 to 1.92 mm, consistent with other studies involving Chinese populations. Chou et al. [32], Liu et al. [33], and Shao et al. [26] reported GTs ranging from 1.05 to 1.23 mm in populations from Taiwan, Hong Kong, and Nanjing, respectively, which were less apparent than GTs from the Caucasian population as well as from populations from Singapore [25] or Malaysia [34], indicating that even in the east Asian region, people from different countries exhibit different gingival characteristics.

Sex was also a major factor associated with the gingival phenotype, although inconsistent conclusions have been reported. Esfahanizadeh et al. [35] and Rodrigues et al. [13] found a higher prevalence of the thin biotype in women than in men, while Shah et al. [28], Collins et al. [36], Alhajj et al. [37], and Fischer et al. [38] reported no significant relationship between GT and sex in the maxillary anterior region. In the present study, the thin gingival biotype was more frequent in women than in men, and GT and BTs were significantly lower in women than in men at all sites except for GT at PMs. Egreja et al. [27] reported no significant difference in KGW between men and women; however, the present study showed that KGW was higher in men than in women. These conflicting results may be attributable to racial differences and the inclusion of PMs in the present study. The present study revealed a difference in the gingival phenotype distribution between men and women in the maxillary anterior region and suggested that different cutoffs should be used to differentiate between thin or thick gingiva in men and women when clinically evaluating the gingival phenotype.

During the past years, the gingival phenotype distribution has been evaluated across participants; however, different tooth types may exhibit different gingival phenotypes in the same patient. Muller et al.'s [11], Fischer et al.'s [38], and Vandana et al.'s [39] studies showed the effect of tooth sites on the gingival phenotype and found that thin gingiva correlated with the canine eminence. In the present study, based on probe transparency, 51% of Cs showed the thick gingival biotype, and the prevalence of the thick gingival biotype was 46% among CIs, 48% among LIs, 46% among PMs, although the differences were not statistically significant. GTs differed significantly among tooth sites, with PMs exhibiting the highest GT of 1.12 mm, followed by CIs, LIs, and Cs, exhibiting the lowest GT of 0.79 mm. Similar to GT, PMs exhibited the highest BTs of 0.95 (BT1) and 0.94 (BT2) mm, followed by CIs, Cs, and LIs, exhibiting the lowest BTs of 0.76 (BT1)

and 0.67 (BT2) mm. LIs had the highest KGW of 5.78 mm, followed by CIs, Cs, and PMs, exhibiting the lowest KGW of 5.33 mm. The results of the present study were consistent with those of other studies with similar GT distribution and demonstrated differences in the gingival phenotype among different teeth of the same patient. This finding should be taken into consideration in clinical practice.

However, the present study has some limitations. First, transgingival probing was performed under local anesthesia. Infusion of the anesthetic and distortion of the probe might have affected the precision of the measurement, and a non-standardized degree of force during transgingival probing could have penetrated the periosteum and even the lamina dura. Second, transgingival probing was performed at the level 1 mm apical to the gingival margin, and GT varied across landmarks. Therefore, an objective numeric measurement threshold distinguishing thin from thick gingiva would have useful clinical applications. Third, subtle variations in gingival color and pigmentation could influence a clinician's ability to evaluate probe transparency. Nik-Azis et al.'s [34] study showed that gingival pigmentation significantly affected the probe transparency assessment. Finally, we excluded the teeth with gingival recession or a history of periodontal surgery. These factors limit the applicability of the present results.

In conclusion, the present study showed that GT and KGW correlated positively in the maxillary anterior region. Furthermore, the gingival phenotype correlated positively with the bone morphotype and varied within and among individuals. Sex was a factor associated with the gingival biotype and bone morphotype. GT measured with transgingival probing with a cutoff of 0.8 mm could serve as an objective measure to distinguish among gingival phenotypes.

Author contributions Y.Z. F.X. and Y.C. conceptualized the overall strategy. Y.Z and F.C. equally contributed to the clinical translation and implementation, and preparation of the manuscript and figures. N.K. and JY.D. designed and performed the statistical analyses and preparation of the manuscript, including text and figures. F.X. and Y.C. provided supervision and wrote and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding The study was supported by National Natural Science Foundations of China (Project Number: 81800978) and the Peking University School and Hospital of Stomatology (PKUSSNCT- 20B10, PKUSS20200105). The funders had no role in the design of the study, collection, analysis or interpretation of the data, or in writing the manuscript.

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

Declarations

Ethics approval and consent to participate The Ethics Committee of the Peking University School and Hospital of Stomatology approved the study protocol. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Conflicts of interests The authors declare that they have no conflict of interest.

Competing interests The authors declare that they have no conflict of interest.

References

1. Kim DM, Bassir SH, Nguyen TT (2020) Effect of gingival phenotype on the maintenance of periodontal health: An American Academy of Periodontology best evidence review. J Periodontol 91:311–338. https://doi.org/10.1002/JPER.19-0337
2. Jepsen S, Caton JG, Albandar JM, Bissada NF, Bouchard P, Cortellini P, Demirel K, de Sanctis M, Ercoli C, Fan J, Geurs NC, Hughes FJ, Jin L, Kantarci A, Lalla E, Madianos PN, Matthews D, McGuire MK, Mills MP, Preshaw PM, Reynolds MA, Sculean A, Susin C, West NX, Yamazaki K (2018) Periodontal manifestations of systemic diseases and developmental and acquired conditions: Consensus report of workgroup 3 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. J Periodontol 89(Suppl 1):S237–S248. https://doi.org/10.1002/JPER.17-0733
3. Claffey N, Shanley D (1986) Relationship of gingival thickness and bleeding to loss of probing attachment in shallow sites following nonsurgical periodontal therapy. J Clin Periodontol 13:654–657. https://doi.org/10.1111/j.1600-051x.1986.tb00861.x
4. van Eekeren P, van Elsas P, Tahmaseb A, Wismeijer D (2017) The influence of initial mucosal thickness on crestal bone change in similar macrogeometrical implants: a prospective randomized clinical trial. Clin Oral Implants Res 28:214–218. https://doi.org/10.1111/clr.12784
5. Chen ZY, Zhong JS, Ouyang XY, Zhou SY, Xie Y, Lou XZ (2020) Gingival thickness assessment of gingival recession teeth. Beijing Da Xue Xue Bao Yi Xue Ban 52:339–345. https://doi.org/10.19723/j.issn.1671-167X.2020.02.023
6. Aslan S, Clauser T, Testori T, Del Fabbro M, Rasperini G (2021) A Novel Technique for the Estimation of Gingival Thickness: A Preliminary Study. Int J Periodontics Restorative Dent 41:571–577. https://doi.org/10.11607/prd.4947
7. Fischer KR, Buchel J, Testori T, Rasperini G, Attin T, Schmidlin P (2021) Gingival phenotype assessment methods and classifications revisited: a preclinical study. Clin Oral Investig 25:5513–5518. https://doi.org/10.1007/s00784-021-03860-5
8. Bertl K, Al-Hotheiry M, Sun D, Olofsson J, Lettner S, Gotfredsen K, Stavropoulos A (2022) Are colored periodontal probes reliable to classify the gingival phenotype in terms of gingival thickness? J Periodontol 93:412–422. https://doi.org/10.1002/JPER.21-0311
9. Kan JY, Morimoto T, Rungcharassaeng K, Roe P, Smith DH (2010) Gingival biotype assessment in the esthetic zone: visual versus direct measurement. Int J Periodontics Restorative Dent 30:237–243. https://doi.org/10.11607/prd.00.0918
10. Sharma S, Thakur SL, Joshi SK, Kulkarni SS (2014) Measurement of gingival thickness using digital vernier caliper and ultrasonographic method: a comparative study. J Investig Clin Dent 5:138–143. https://doi.org/10.1111/jicd.12026
11. Muller HP, Heinecke A, Schaller N, Eger T (2000) Masticatory mucosa in subjects with different periodontal phenotypes. J Clin Periodontol 27:621–626. https://doi.org/10.1034/j.1600-051x.2000.027009621.x

12. Alpiste-Illueca F (2004) Dimensions of the dentogingival unit in maxillary anterior teeth: a new exploration technique (parallel profile radiograph). Int J Periodontics Restorative Dent 24:386–396. https://doi.org/10.11607/prd.00.0587
13. Rodrigues DM, Petersen RL, de Moraes JR, Barboza EP (2022) Gingival landmarks and cutting points for gingival phenotype determination: A clinical and tomographic cross-sectional study. J Periodontol 93:1916–1928. https://doi.org/10.1002/JPER.21-0615
14. Aguilar-Duran L, Mir-Mari J, Figueiredo R, Valmaseda-Castellon E (2020) Is measurement of the gingival biotype reliable? Agreement among different assessment methods. Med Oral Patol Oral Cir Bucal 25:e144–e149. https://doi.org/10.4317/medoral.23280
15. Malpartida-Carrillo V, Tinedo-Lopez PL, Guerrero ME, Amaya-Pajares SP, Ozcan M, Rosing CK (2021) Periodontal phenotype: A review of historical and current classifications evaluating different methods and characteristics. J Esthet Restor Dent 33:432–445. https://doi.org/10.1111/jerd.12661
16. Wang J, Cha S, Zhao Q, Bai D (2022) Methods to assess tooth gingival thickness and diagnose gingival phenotypes: A systematic review. J Esthet Restor Dent 34:620–632. https://doi.org/10.1111/jerd.12900
17. Frost NA, Mealey BL, Jones AA, Huynh-Ba G (2015) Periodontal Biotype: Gingival Thickness as It Relates to Probe Visibility and Buccal Plate Thickness. J Periodontol 86:1141–1149. https://doi.org/10.1902/jop.2015.140394
18. Nikiforidou M, Tsalikis L, Angelopoulos C, Menexes G, Vouros I, Konstantinides A (2016) Classification of periodontal biotypes with the use of CBCT. A cross-sectional study Clin Oral Investig 20:2061–2071. https://doi.org/10.1007/s00784-015-1694-y
19. Amid R, Mirakhori M, Safi Y, Kadkhodazadeh M, Namdari M (2017) Assessment of gingival biotype and facial hard/soft tissue dimensions in the maxillary anterior teeth region using cone beam computed tomography. Arch Oral Biol 79:1–6. https://doi.org/10.1016/j.archoralbio.2017.02.021
20. De Rouck T, Eghbali R, Collys K, De Bruyn H, Cosyn J (2009) The gingival biotype revisited: transparency of the periodontal probe through the gingival margin as a method to discriminate thin from thick gingiva. J Clin Periodontol 36:428–433. https://doi.org/10.1111/j.1600-051X.2009.01398.x
21. Eghbali A, De Rouck T, De Bruyn H, Cosyn J (2009) The gingival biotype assessed by experienced and inexperienced clinicians. J Clin Periodontol 36:958–963. https://doi.org/10.1111/j.1600-051X.2009.01479.x
22. Stein JM, Lintel-Hoping N, Hammacher C, Kasaj A, Tamm M, Hanisch O (2013) The gingival biotype: measurement of soft and hard tissue dimensions - a radiographic morphometric study. J Clin Periodontol 40:1132–1139. https://doi.org/10.1111/jcpe.12169
23. Cook DR, Mealey BL, Verrett RG, Mills MP, Noujeim ME, Lasho DJ, Cronin RJ Jr (2011) Relationship between clinical periodontal biotype and labial plate thickness: an in vivo study. Int J Periodontics Restorative Dent 31:345–354. https://doi.org/10.11607/prd.00.0985
24. Hsu YT, Huang NC, Wong A, Cobb C, Lee S, Mikail Y, Kao RT (2020) Periodontal Risk Assessment Based on Dental and Gingival Morphology: A Comparative Analysis of African Versus Asian American Cohorts. Clin Adv Periodontics 10:224–230. https://doi.org/10.1002/cap.10117
25. Lee WZ, Ong MMA, Yeo AB (2018) Gingival profiles in a select Asian cohort: A pilot study. J Investig Clin Dent 9:e12269. https://doi.org/10.1111/jicd.12269
26. Shao Y, Yin L, Gu J, Wang D, Lu W, Sun Y (2018) Assessment of Periodontal Biotype in a Young Chinese Population using Different Measurement Methods. Sci Rep 8:11212. https://doi.org/10.1038/s41598-018-29542-z
27. Egreja AM, Kahn S, Barceleiro M, Bittencourt S (2012) Relationship between the width of the zone of keratinized tissue and thickness of gingival tissue in the anterior maxilla. Int J Periodontics Restorative Dent 32:573–579. https://doi.org/10.11607/prd.00.1097
28. Shah R, Sowmya NK, Mehta DS (2015) Prevalence of gingival biotype and its relationship to clinical parameters. Contemp Clin Dent 6:S167–S171. https://doi.org/10.4103/0976-237X.166824
29. Mallikarjun S, Babu HM, Das S, Neelakanti A, Dawra C, Shinde SV (2016) Comparative evaluation of soft and hard tissue dimensions in the anterior maxilla using radiovisiography and cone beam computed tomography: A pilot study. J Indian Soc Periodontol 20:174–177. https://doi.org/10.4103/0972-124X.170813
30. La Rocca AP, Alemany AS, Levi P Jr, Juan MV, Molina JN, Weisgold AS (2012) Anterior maxillary and mandibular biotype: relationship between gingival thickness and width with respect to underlying bone thickness. Implant Dent 21:507–515. https://doi.org/10.1097/ID.0b013e318271d487
31. Shafizadeh M, Amid R, Tehranchi A, Motamedian SR (2022) Evaluation of the association between gingival phenotype and alveolar bone thickness: A systematic review and meta-analysis. Arch Oral Biol 133:105287. https://doi.org/10.1016/j.archoralbio.2021.105287
32. Chou YH, Tsai CC, Wang JC, Ho YP, Ho KY, Tseng CC (2008) New classification of crown forms and gingival characteristics in taiwanese. Open Dent J 2:114–119. https://doi.org/10.2174/1874210600802010114
33. Liu F, Pelekos G, Jin LJ (2017) The gingival biotype in a cohort of Chinese subjects with and without history of periodontal disease. J Periodontal Res 52:1004–1010. https://doi.org/10.1111/jre.12471
34. Nik-Azis NM, Razali M, Goh V, Ahmad Shuhaimi NN, MohdNazrin NAS (2023) Assessment of gingival thickness in multi-ethnic subjects with different gingival pigmentation levels. J Clin Periodontol 50:80–89. https://doi.org/10.1111/jcpe.13723
35. Esfahanizadeh N, Daneshparvar N, Askarpour F, Akhoundi N, Panjnoush M (2016) Correlation Between Bone and Soft Tissue Thickness in Maxillary Anterior Teeth. J Dent (Tehran) 13:302–308
36. Collins JR, Pannuti CM, Veras K, Ogando G, Brache M (2021) Gingival phenotype and its relationship with different clinical parameters: a study in a Dominican adult sample. Clin Oral Investig 25:4967–4973. https://doi.org/10.1007/s00784-021-03806-x
37. Alhajj WA (2020) Gingival phenotypes and their relation to age, gender and other risk factors. BMC Oral Health 20:87. https://doi.org/10.1186/s12903-020-01073-y
38. Fischer KR, Buchel J, Kauffmann F, Heumann C, Friedmann A, Schmidlin PR (2022) Gingival phenotype distribution in young Caucasian women and men - An investigative study. Clin Exp Dent Res 8:374–379. https://doi.org/10.1002/cre2.482
39. Vandana KL, Savitha B (2005) Thickness of gingiva in association with age, gender and dental arch location. J Clin Periodontol 32:828–830. https://doi.org/10.1111/j.1600-051X.2005.00757.x