Correlational Research on the 3D Digital Models Based Measurement for Periodontal Biotypes of Crown and Gingival Morphology

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Abstract

Background This paper aims to quantitatively study the clinical parameters of crown and gingival morphology (CGM) of the maxillary anterior teeth (MAT), and analyze the correlation of parameters between periodontal biotype(PB) and CGM, with a view to providing objective standards for periodontal biotyping.Methods The 3D maxillary digital models of 56 experimental subjects were obtained through an intra-oral scanner, and an array of parameters measued with the SpaceClaim software, such as gingival angle (GA), papilla width (PW), papilla height (PH), crown length (CL), crown width (CW), crown width/crown length ratio (CW/CL), bucco-lingual width of the crown (BLW), contact surface width (CSW), and contact surface height/crown length ratio (CS/CL). Then, the PBs were judged through the transparency method of the periodontal probe through the gingival sulcus. Logistic regression was adopted to analyze the independent influence factors of PB, and the receiver operating characteristic curve (ROC curve) used to analyze the optimal cutoff value of independent influence factors.Results There is statistical difference to the parameters of CGM of the MAT at left and right side. The thick biotype accounts for 69.6%, and the parameters of gender, GA, PW, PH, CW and CW/CL are significantly correlated with PBs ($P \leq 0.043$). GA (OR=1.206) and PW (OR=5.048) are the independent predictive factors of PBs, their areas under the ROC curve (AUC) are 0.807 and 0.881, respectively, and their optimal cutoff values are 95.95° and 10.01mm, respectively.Conclusion The CGMs of the MAT at the left and right side is symmetrical. The thin biotype accounts for a small portion, and GA and PW are the independent influence factors of PBs. When GA is 95.95° and PW is 10.01mm, it is the optimal cutoff value to categorize experimental subjects into thick biotype.

Background

In 1989, Seibert and Lindhe [1] proposed the concept of PB, i.e., the thickness of buccolingual gingiva that can be divided into thick biotype and thin biotype. There is difference in CGM coordination as well as the stability of gingival margin between different PBs, which directly influences the esthetic effect of restoration and patients satisfaction. Besides, some scholars hold that PB plays an important influence upon the treatment effect and prognosis of periodontal surgery, plantation and orthodontics [2-4]. Therefore, it is of crucial importance to correctly judge the PBs in dental treatment.

In recent years, more and more scholars have started to study the correlation of PBs with clinical parameters like gingival thickness, crown morphology, and alveolar bone morphology[5-11]. De Rouck et al. [5]. measured the intra-oral indexes likes CW/CL, keratinized gingival width, and papilla height using caliper and periodontal probe, and divided PBs into thin-scalloped biotype, thick-flat biotype and thick-scalloped biotype with the cluster analysis method. Stein et al. [10] conducted intra-oral measurement of keratinized gingival width and gingival thickness using periodontal probe, measured CW/CL and papilla height with image analysis software, and explore the correlation of parameters like gingival thickness and CW/CL. However, there are few studies involving the correlation of PBs with maxillary margin and papilla width, let alone the independent influence factors of PBs.

The methods of using caliper and periodontal probe to measure the clinical parameters of gingival morphology are subject to the defects of inconvenience and low accuracy. If image measurement software is adopted, the measurement results are inclined to be influenced by the position of the head, since most literature has made no unified stipulation upon the spatial position of head [9, 12]. With the rapid development of computer technology, partial scholars have creatively introduced the CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) technology into the esthetic restoration of anterior teeth. Lee SP et al. [13] analyzed the correlation between PBs and the gingival papilla of the MAT using 3D digital models; Wong et al. [14] explored the esthetic relations between the incisal edge of the MAT and the upper border of the lower lip using 3D digital models.

This research quantitatively analyzes the clinical parameters of MAT like GA, PW and PH using intra-oral scanner and SpaceClaim, with a view to providing more accurate reference for the computer-aided anterior teeth esthetic analysis and design. The transparency method of the periodontal probe through the gingival sulcus is used for periodontal biotyping, thereby exploring the correlation of the PBs of the right maxillary central incisor with the clinical parameters of gingiva and crown, and analyzing the cutoff value of independent influence factors in the hope of providing objective standards for periodontal biotyping.

Methods

Research subject and inclusion criteria

From January 2018 to June 2018, the on-campus students and young nurses from the School of Stomatology of Shandong University were selected as experimental subjects: 56 in total (including 13 males and 43 females), Han nationality, average age 23.6 ± 2.8. Inclusion criteria: 1) the MAT and the maxillary first molar at both sides were in orderly alignment and had no anodontia, interspersed diastema, wedge-shaped defect, dental caries, dental fillings and restorations; 2) healthy periodontal tissue: plaque index and gingival index ≤1, without obvious gingival recession or periodontal disease history; 3) no sleep bruxism history, no attrition of full dentition (attrition score ≤2); 4) normal or I degree deep overbite and deep overjet; 5) normal occlusal curve; 6) no administration of gingival hyperplasia related medicines within the latest 3 months; 7) no obvious gingival color pigmentation; and 8) age: 18-40.

This research proposal was conducted in full accordance with the World Medical Association Declaration of Helsinki. Besides, this research has been approved by the Medical Ethics Committee of the Affiliated Stomatological Hospital to Shandong University (NO.R20180502), and obtained the written informed consent of all research subjects.

Obtainment of 3D digital models

The maxillary casts of experimental subjects were scanned through an intra-oral scanner, with the STL format model files exported, which were numbered #1 - #56, respectively. Then, the *.STL files were imported into SpaceClaim software to generate 3D digital models (Fig. 1).

Determination of reference plane and esthetic landmark

The experiment steps were the same as described in our previously published paper [15]. Simply speaking, for the sake of the description of the positional relation between maxillary dentition and gingiva landmarks, an occlusal plane was selected as the horizontal reference plane, with 22 esthetic landmarks like gingival zenith marked and the vertical bisected middle surface along the long axis of the clinical crown (VBMS) drawn. The intersection between VBMS and gingival margin at the labial side was marked as the midpoint. (Fig. 2)

CGM index and measurement (accuracy: 0.01mm)

Gingival angle (GA): the angle between the gingival zenith at labial side and the corresponding mesial and distal papilla top [9] (Fig. 2a). Papilla width (PW): the distance between the gingival zeniths of the two adjacent teeth. Each value was then associated with the mesially positioned tooth (Fig. 2a). Papilla height (PH): the shortest distance from the top of the papilla to the segment PW [13]. The mesial PH was recorded for every tooth position (Fig. 2a). Crown length (CL): the distance from gingival zenith to the midpoint of incisal edge (or dental cusp)(Fig. 2a). Crown width (CW): the distance between the approximal tooth surfaces, was recorded at the border between the middle and the cervical portion(Fig. 2a). Bucco-lingual width of the crown (BLW): the distance from the gingival margin at palate side closest to the apical top to the gingival midpoint at labial side [9](Fig. 2b). Contact surface width (CSW): the distance between the contact areas of the most apical portion and the most incisal portion. The mesial CSW was recorded for every tooth position(Fig. 2a). Contact surface height (CS): the shortest distance from the most apical portion point in the mesial contact area to the incisal edge [12]. The mesial contact area height was recorded every tooth position, and CS/CL value calculated(Fig. 2a). All measurement data was completed by the same one clinical researcher. After the interval of 1 month, 6 samples were randomly taken from the master samples for re-measurement.

(**a**) Landmark 1 and 2, the mesioincisal angle of the maxillary central incisors at both sides; Landmark 3, the midpoint of the mesioincisal angle ligature between the maxillary central incisors at both sides; Landmark 4 and 5, the mesiobuccal cusp tip of the maxillary right and left first molars; Landmark 6-11, the gingival edege apical top of the MAT at labial side; Landmark 12-16, the top of the gingival papilla of the MAT; Landmark 23, the midpoint of right maxillary central incisors gingival edge midpoint.

(**b**) Landmark 17-22, the top at the direction of gingival edge of the MAT at palate side.

Transparency of the periodontal probe through the gingival sulcus to evaluate PBs

Experimental subjects lay flatly on the treatment chair, with the occlusal plane perpendicular to the ground. After the area of the MAT was dried and a black background put into the mouth, the standard Williams periodontal probe (KPW, Shanghai Kangqiao Dental Instruments Factory, Shanghai, China) was placed into the culcus at the midfacial aspect of the right maxillary central incisor. The periodontal probe was parallel to the long axis of the clinical crown, and the probing depth was 1 mm (When the probing depth was 1mm, the probe would reach to the bottom of the gingival sulcus) [17]. The digital camera (Nikon D750, Nikon Corporation, Tokyo, Japan) equipped with microspur -105mm lens (AF-S VR 105mm f/2.8G IF-ED, NIKON CORPORATION, TOKYO JAPAN) and microspur flashlight (Nikon R1C1, NIKON CORPORATION, TOKYO, JAPAN) was used to take photos in a standardized manner: 1) unified shooting conditions like light, background, distance; 2) adoption of the same camera setting parameters; and 3) the checked teeth were put at the center of photos, which should include around two natural teeth. All the examinations were completed by the same one postgraduate, and all shooting was done by the same one nurse.

The photos of all experimental subjects were randomly put into the PPT file (Microsoft). After training and alignment by examiners, three postgraduates independently conducted PB qualitative biotyping according to the judgement standards of PBs.

The judgement standards of PBs [5, 10, 13, 18, 19] : 1) for thin biotypes, the probe was visible through the gingival tissue when placed within the gingival sulcus (Fig. 3a); 2) for thick biotypes, the probe was invisible through the gingival tissue when placed within the gingival sulcus (Fig. 3b).

After an interval of two weeks, a second time of qualitative biotyping was independently conducted, in the hope of lowering the bias in the first time. The determination of PBs for every experimental subject must be based on the fact that the biotyping of two out of three examiners was consistent, with Kappa adopted to verify the reliability.

Statistical analysis methods

For all the continuous variables (e.g., GA and PW), the test-retest reliability of the examiners was examined through the Pearson correlation coefficient test in statistical software (IBM SPSS Statistics 24.0, IBM, Chicago, USA), while the intra-examiner repeatability was evaluateed with Kappa test. Besides, Shapiro-Wilks Test was adopted to verify the normal distribution of data, and the average of clinical parameters was further analyzed by verifying that there was no statistical difference in measurement results of clinical parameters of the same teeth position at both sides through Wilcoxon Signed Rank Test and Paired Sample *t* Test. The normal distribution of data was re-verified, with measurement data expressed in Mean±SD, and variance analysis was adopted for for the comparison between groups. Enumeration data were expressed in frequency, and chi-square test ($\chi 2$ test) adopted for the comparison between groups. PB was taken as a dependent variable, while the factors with variance analysis $P \le 0.2$ were taken as independent variables. Forward: LR method was used for logistic regression to study the independent influence factors of PBs (inclusion equation standard 0.05, elimination standard 0.10). ROC curve analysis was re-conducted to evaluate the value of the factors that finally entered the logistic regression model for the diagnosis of PBs. The significance level was set at 5%.

Results

Test-retest reliability results showed that: except for the Pearson correlation coefficient in the PH associated with the mesial aspect of the maxillary canines that was low ($r=0.657$, $P<0.001$), those of other indexes were relatively high ($r\geq0.916$, $P<0.001$), indicating the repeatability of the experiment; the average Kappa coefficient of the transparency of the periodontal probe through the gingival sulcus was 0.733 ($P<0.001$), indicating the sound reliability of the evaluation method. The Wilcoxon Signed Rank Test and Paired Sample *t* Test results showed that: there was no significant statistical difference in the measurement results of the clinical parameters like GA and PW for the same teeth position and interdental position at both sides ($p\geq0.069$).

The CGM characteristics of the MAT of the experimental subjects are as shown in Table 1.

The periodontal biotyping of the experimental subjects is as shown in Table 2. Results showed that: among the 56 experimental subjects, the thick biotype accounted for the largest proportion, around 69.6%.

For different PBs, the CGM characteristics of right maxillary central incisors are as shown in Table 3. An analysis of variance (ANOVA) showed that there was statistical difference in gender, GA, PW, PH, CW, and CW/CL for different PBs ($P\leq0.043$), and no statistical difference in CL, BLW, CSW, and CS/CL ($p\geq0.102$).

Table 4 presents the logistic regression results of PB multiple factors, showing that GA (OR=1.206, P=0.016) and PW (OR=5.048, P=0.002) were the independent influence factors of PBs. Logistic regression model was used to re-categorize PBs, with a total accuracy of 85.7%, as shown in Table 5.

A ROC curve was drawn with GA and PW as the test variables, as shown in Fig. 4. The AUCs of GA and PW were 0.807 and 0.881, respectively, and the optimal cutoff values of GA and PW were 95.95° and 10.01mm, respectively. The combined AUC of GA and PW was 0.935, larger than the singular AUC for GA and PW, showing that the combined diagnosis of GA and PW contributes to uplifting the diagnostic efficiency of PBs. In other words, when the GA and PW of the right maxillary central incisor are 95.95° and 10.01mm, respectively, it turns out to be the optimal cutoff value for categorizing experimental subjects into thick biotype, as shown in Table 6.

Discussion

In clinical practice, different PBs may have different reactions to inflammation and various dental treatment. To obtain an ideal treatment effect, it is necessary to judge the PBs of patients in advance. This paper quantitatively analyzes the CGM morphology clinical parameters of upper anterior teeth using 3D digital models, in the hope of providing more accurate references for the esthetic analysis and design of computer-aided anterior teeth, determining the cutoff value of gingiva and crown clinical parameters, and establishing clinical guidelines to offer quantitative guidance for periodontal biotyping.

This research shows that among the 56 experimental subjects, thick biotype accounted for the most, around 69.6%, while thin biotype accounted for 30.4%; and there was statistical difference in PB between males and females,which is consistent with the results by De Rouck et al [5]. However, Lee et al. [13] held that gender had no significant influence upon PBs, and thin biotype held about 21.8%. According to Frost NA et al. [18], thin biotype held about 7%. Sample size and ethnic differences therein may be the major reasons for the inconsistency of results.

The contour of gingival margin is determined by parameters like gingival angle, papilla width, and papilla height. The GA averages of the maxillary central incisor, lateral incisor and canine of all experimental subjects were 98.19±7.69°, 96.24±10.03° and 89.45±6.63°, respectively. However, Olsson et al. [9] argued that the GAs for the maxillary central incisor, lateral incisor and canine were 86.60°, 82.80° and 80.29°, respectively. The measurement methods may be the major reason for the inconsistency of the results. Olsson et al. Worked out GA through cosine function using intra-oral photos. This experiment directly measured GA through 3D digital models, which is more simple, convenient and accurate in reflecting the spatial positional relation of teeth and gingiva. The logistic regression model in this experiment showed that GA (P=0.016, OR=1.206) was one of the independent influence factors of PBs. Research showed that the central incisor GAs of thin biotype and thick biotype were 92.73± 6.21° and 101.68±8.03°, respectively. The conclusion is consistent with the viewpoint of Olsson [9] and Zhou et al. [4], suggesting that the gingival angle of thin biotype is smaller and the gingival margin more curved.

The morphology of gingival papilla is a major evaluation index for current various anterior teeth esthetic evaluation systems. This research showed that: the PWs of the maxillary central incisor, lateral incisor and canine of all the experimental subjects were 10.05±0.79mm, 7.83±0.60mm and 7.97±0.65mm, respectively, which is consistent with the findings by Zhou et al. [4]. The logistic regression model of the right maxillary central incisor indicates that PW has a significant influence upon PBs (P=0.002, OR=5.048), i.e., making the gingival papilla of the maxillary central incisor of thin biotype narrower, but there are few studies invoving the correlation between PB and PW.

Olsson et al. [9] held that the PH for the maxillary central incisor, lateral incisor and canine was respectively 4.16mm, 4.02mm and 4.21mm, but the results in this experiment are 3.65±0.59mm, 3.37±0.54mm, 3.28±0.57mm. This disparity may be attributed to the differences in experiment subjects and measurement methods. Besides, ANOVA test shows that there is statistical difference (P=0.027) between PH and PB, while logistic multi-factor regression analysis suggests that PH is not an independent influence factor of PB. De Rouck et al. [5] also held that there was statistical difference in PH between PB, while Olsson [9] and Stein [10] et al. claimed that there was no obvious correlation between gingival thickness and PH. Lee SP et al. [13] found out that the sum of five gingival papilla heights of the MAT larger than 24 mm was the identification standard for thin biotype, and PB had no obvious correlation with the papillary height between two central incisors. The imparity in measurement method and periodontal biotyping method may be the major reason for the above differences.

Stein et al. [10] measured and calculate CW/CL using image measurement software, finding that CW/CL and PB were closely related, and therefore could be taken as the predictive index for gingival thickness. The ANOVA test in this research shows that there is no obvious statistical significance between CW/CL and PB, but in logistic regression model, CW/CL is eliminated out of the regression equation, indicating that it is not the independent influence factor of PB. This is consistent with the research results by Olsson [9] and Eger [20]. This is possibly related to the difficulty in determining the proper reference points, because CL is subject to the influence of attachment loss, gingival inflammation and incisal attrition while CW is subject to the influence of gingival papilla [9]. Moreover, differences in ethnicity and region may lead to different crown morphologies.

Olsson [9] obtained the BLWs of the maxillary central incisor, lateral incisor and canine through measuring casts, which were 7.33±0.56mm, 6.51±0.57mm and 8.29±0.65mm, respectively, aruging that gingival thickness and BLW were significantly correlated. This research believes that the BLWs of the maxillary central incisor, lateral incisor and canine are 7.22±0.53mm, 6.56±0.52mm, 8.38±0.48mm, respectively, with no correlation between BLW and PB found. Such an imparity may be attributed to the differences in experimental subjects and PB judgement method.

Tarnow et al. [21] held that the esthetic effect of gingival papilla was associated with the position of the contact area. This research shows that the CSWs of the maxillary central incisor, lateral incisor and canine are 4.39±0.72mm, 3.56±0.56mm, 2.62±0.57mm, respectively, and the CS/CL is respectively 59.7%, 62.3% and 63.5%. Moreover, compared with thin biotype, the contact surface of thick biotype has a large width, and the most apical portion of the contact area is closer to gingival margin, but no statistical difference has been found between PBs. Meanwhile, Gobbato et al. [12] categorized the maxillary central incisor, finding that the most apical portion of the contact area in the triangular group was closer to the incisal edge, while that in the square group was closer to gingival margin.

Most of the research focuses on the correlation of PB with the morphology of soft and hard tissues [5-8, 10, 11, 17, 19, 22-24], with little involving the influence of independent factors on PB diagnosis efficiency. The logistic regression results in this research show that the right central incisor GA and PW are important predictive factors of PB; and when GA increases every 1°, the probability of experimental subjects being diagnosed as thick biotype increases 1.206 times, and when PW increases every 1 mm, the probability of being diagnosed into thick biotype increases 5.048 times. This supports the hypothesis that "compared with thick biotype, the free gingival margin at the labial side of thin biotype is more curved and the gingival papilla narrower" [5, 9, 16, 25]. It is discovered that the GA, PW and combined AUC are 0.807, 0.881, 0.935, respectively, indicating GA and PW combined diagnosis can help improve the diagnostic efficiency of PB. In this experiment, when the GA and PW of the right maxillary central incisor are 95.95° and 10.01mm, it turns ou to be the optimal cutoff value to categorize experimental subjects into thick biotype. It indicates that when the GA and PW of the right maxillary central incisor are GA≥95.95° and ≥10.01mm, there is a higher possibility of categorizing experimental subjects into thick biotype. Frost NA et al. [18] analyzed the relation between gingival thickness and PB using ROC curve, failing to find a suitable gingival thickness threshold to judge thick biotype.

This research explores the CGM parameters and their correlation with PB using 3D digital models, but it is beset by the problems of small sample size, uneven gender ratio, and single focus on the correlation of the right maxillary central incisor PB with CGM clinical parameters. Therefore, in future studies, it is necessary to expand the sample size balance the gender ratio, and take into consideration the correlation of the periodontal biotyps at different teeth positions with CGM. In addition, the influence factors included into this research are limited, which may have ignored the influence of other factors upon PB, so future research is to include the influence factors like alveolar bone morphology, keratinized gingival width and gingival thickness, in the hope of providing powerful evidence to clinicians' diagnosis of PBs. To clarify whether GA and PW can benefit the PB diagnosis efficiency, it is also necessary to carry out randomized controlled trial for verification.

Conclusions

With the occlusal plane as the reference plan, the CGM at both sides is symmetrical. The thin biotype accounts for a small portion; in the case of a thin PB, the free gingival margin at the labial side of central incisor is more curved, and the gingival papilla narrower. For a long-narrow crown, the bucco-lingual width of the crown is smaller, the contact surface is larger, and the most apical portion of the contact area is closer to the incisal edge. Moreover, GA and PW are the independent influence factors to the PB of the right maxillary central incisor. When GA is 95.95° and PW is 10.01mm, it turns out to be the optimal cutoff value to categorize experimental subjects into thick biotype.

Abbreviations

CGM: Crown and gingival morphology; MAT: Maxillary anterior teeth; PB: Periodontal biotype;GA: Gingival angle; PW: Papilla width; PH: Gapilla height; CL: Crown length; CW: Crown width; CW/CL: Crown width/crown length ratio; BLW: Bucco-lingual width of the crown; CSW: Contact surface width; CS/CL: Contact surface height/crown length ratio; ROC curve: Receiver operating characteristic curve; AUC: Areas under the ROC curve; CAD/CAM: Computer aided design/computer aided manufacturing; VBMS: Vertical bisected middle surface along the long axis of the clinical crown; CS: Contact surface height

Declarations

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Authors' contributions

XJY and XPK participated in conception and design of the work, collecting data, and drafted the manuscript. BYW contributed in data collection. TZ and MYJ performed the statistical analysis and participated in its design. XYL participated in collecting data. HQS participated in the acquisition, analysis, interpretation of data and draft the manuscript. All authors have made substantive contribution to this study and/or manuscript, and all have reviewed the final paper prior to its submission. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1 The CGM characteristics of MAT (Mean±SD)

Factor	Central incisor Mean±SD	Lateral incisor Mean±SD	Canine Mean±SD
GA(°)	98.19± 7.69	96.24±10.03	89.45±6.63
PW(mm)	10.05±0.79	7.83±0.60	7.97±0.65
PH(mm)	3.65±0.59	3.37±0.53	3.28±0.57
CL(mm)	9.53±0.77	8.26±0.77	9.09±0.79
CW(mm)	7.51±0.62	5.84±0.48	6.64±0.52
CW/CL	0.791±0.077	0.713±0.081	0.735±0.070
BLW(mm)	7.22±0.53	6.56±0.52	8.38±0.48
CSW(mm)	4.39±0.72	3.56±0.56	2.62±0.57
CS/CL	0.597±0.069	0.623±0.070	0.635±0.057

Table 2 The frequency distribution of PBs

	Male participants(n)	Female participants(n)	Total[n(%)]
Thin	1	16	17(30.4)
Thick	12	27	39(69.6)
Total	13	43	56(100)

Table 3 The CGM characteristics of the right maxillary central incisor under different PBs

Index	Thin	Thick	X^2/F	P
Gender			4.281	0.043
GA(°)	92.73±6.21	101.68±8.03	16.704	0.000
PW(mm)	9.43±0.53	10.39±0.61	31.955	0.000
PH(mm)	3.91±0.58	3.53±0.56	5.163	0.027
CL(mm)	9.69±0.81	9.41±0.81	1.428	0.237
CW(mm)	7.15±0.58	7.67±0.61	8.644	0.005
CW/CL	0.736±0.065	0.819±0.078	14.465	0.000
BLW(mm)	7.16±0.53	7.25±0.59	0.264	0.61
CSW(mm)	4.33±0.70	4.50±0.82	0.55	0.462
CS/CL	0.575±0.074	0.611±0.074	2.772	0.102

Table 4 Multi-factor logistic regression of PBs

Influence factor	***OR***	***P***	***OR95%CI***	
			Lower limit	**Upper limit**
GA	1.206	0.016	1.035	1.405
PW	5.048	0.002	2.705	83.710

Table 5 Logistic regression prediction categorization table of PBs

Observed	Predicted		
	Thin	Thick	Percentage Correct
Thin	12	5	70.6
Thick	3	36	92.3
Overall Percentage			85.7

Table 6 Diagnostic value of gingival edge angle and papilla width to PBs

Variables	AUC	95%CI	P	Sensitivity(%)	Specificity	cutoff values
GA(°)	0.807	0.689-0.925	0.000	71.8	76.5	95.95
PW(mm)	0.881	0.774-0.988	0.000	82.1	94.1	10.01
GA and PW	0.935	0.871-0.999	0.000	0.846	0.941	0.76

CI=Confidence Interval

Figures

Figure 1

Intra-oral image and 3d digital models. (a) Intra-oral image (b) 3D digital model

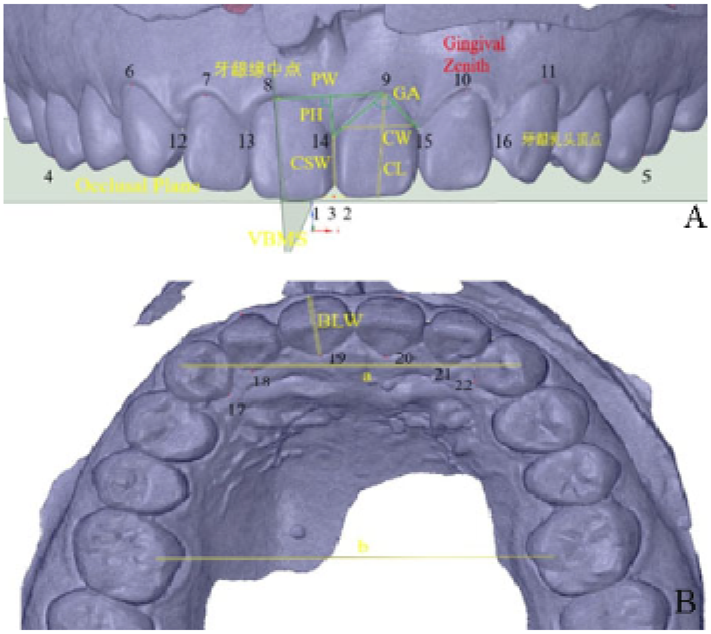

Figure 2

Esthetic-related landmarks

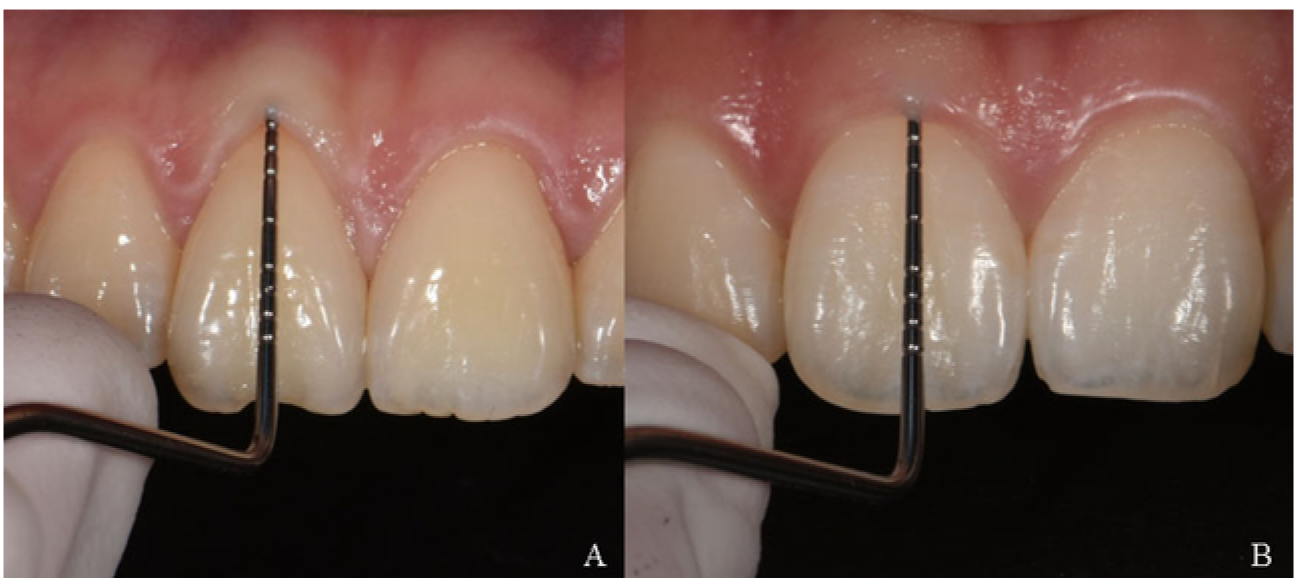

Figure 3

Periodontal biotype (a)Probe visible through marginal tissue, thin biotype; (b)Probe invisible through marginal tissue, thick biotype;

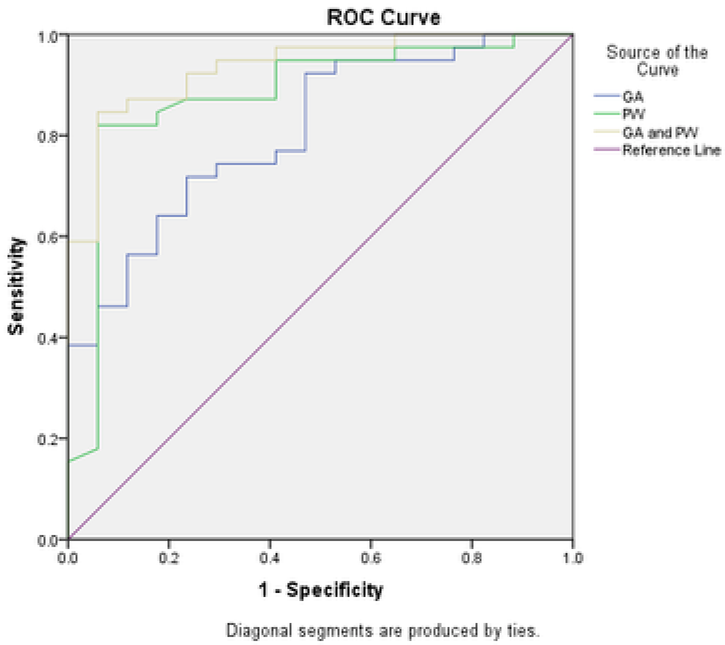

Figure 4

ROC curve plotting sensitivity and specificity values to predict thick biotype at various cutoff values of GA, PW