



Correlation between Clinical Methods and CBCT Cone-Beam Tomography in Periodontal Biotype Determination: Systematic Review

Meriem Ouled Bouallala^{ID}, Khadija Amine^{ID}, Samia Belfellah^{ID}, Jamila Kissa^{ID}

Department of Periodontology, Faculty of Dentistry, University HASSAN II of Casablanca, Casablanca, Morocco
Email: meriem.ouledbouallala@gmail.com, aminekhadija@gmail.com, belfellahsamia@yahoo.fr, jamilakissa@yahoo.fr

How to cite this paper: Ouled Bouallala, M., Amine, K., Belfellah, S. and Kissa, J. (2026) Correlation between Clinical Methods and CBCT Cone-Beam Tomography in Periodontal Biotype Determination: Systematic Review. *Open Access Library Journal*, **13**: e15543. <https://doi.org/10.4236/oalib.1115543>

Received: May 26, 2026

Accepted: July 11, 2026

Published: July 14, 2026

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Abstract

Purpose: This systematic review aims to analyze the correlation between traditional clinical methods and cone-beam computed tomography (CBCT) in determining the periodontal biotype. **Materials AND Methods:** An electronic search was conducted to identify clinical observational and comparative studies comparing CBCT with conventional clinical techniques for assessing gingival and bone thickness. The study followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The risk of bias was evaluated using the Cochrane Collaboration's Risk of Bias tool. **Results:** A total of 11 cross-sectional studies, including 540 patients, were analyzed. The findings revealed a significant increase in gingival thickness and underlying alveolar bone thickness in individuals with a thick periodontal phenotype. Clinical assessment of soft tissue thickness can be easily performed using a periodontal probe by evaluating the transparency of the probe's contour through the gingival sulcus or via transgingival probing with an endodontic K-file under anesthesia. This correlation provides valuable insights during initial examinations, particularly for procedures that may impact periodontal structures, such as immediate implant placement and orthodontic treatment. **Conclusions:** The available evidence suggests that CBCT is a useful adjunctive tool for assessing gingival and alveolar bone thickness and characterizing the periodontal phenotype. However, the current evidence is mainly derived from heterogeneous observational studies, and further prospective investigations are required before definitive conclusions can be drawn regarding its superiority over conventional clinical methods.

Subject Areas

Dentistry

Keywords

Gingival Phenotype, Cone Beam CT, Alveolar Bone Loss, Systematic Review

1. Introduction

Variations in the clinical presentation of mucogingival tissues are described as the periodontal phenotype in the latest classification [1] [2]. This concept encompasses several key parameters, including bone structure, gingival thickness, the width of keratinized tissue, and dental crown morphology. These factors play a crucial role in the periodontium's response to mechanical, chemical, or bacterial challenges, as well as in various dental procedures across different specialties [3].

However, the precise relationship between bone thickness and the overlying gingival tissue remains insufficiently explored. This is mainly due to the absence of standardized, reliable, and reproducible techniques for accurately measuring both soft and hard tissue thickness [4] [5].

Most clinical methods used to assess the periodontal biotype focus primarily on evaluating gingival thickness, with bone thickness often inferred indirectly. These techniques include visual inspection, assessment of periodontal probe visibility through the gingival sulcus at the vestibular level, transgingival probing, and ultrasound imaging.

Conversely, cone-beam computed tomography (CBCT) provides a promising alternative by enabling detailed visualization of both gingival and bone structures, allowing for more precise thickness measurements. This imaging modality offers the potential to better understand the relationship between gingival thickness, bone dimensions, and periodontal phenotype.

Nevertheless, limitations persist regarding the accuracy of these techniques in site-specific tissue thickness measurement. Conflicting study results and ongoing debates about the classification of thick and thin periodontal biotypes highlight the need for further research [6].

The primary objective of this systematic review is to investigate the correlation between clinical evaluation methods and CBCT in determining the periodontal biotype.

2. Material and Methods

A structured protocol was designed in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [7]. The preparation of this manuscript adhered to the PRISMA checklist. The systematic review registration number is INPLASY202650087 and the DOI number is 10.37766/inplasy2026.5.0087.

2.1. Information Sources and Literature Search

A comprehensive search of electronic databases was carried out to identify relevant studies for this review. Four primary sources of scientific evidence were utilized: MEDLINE (PubMed), ScienceDirect, Cochrane, and EBSCO.

The search process was conducted independently by three researchers (O. B. M., A. Kh., and B. S.), each performing the task separately and in triplicate to ensure accuracy and consistency.

The study selection was based on five specific keywords:

- Periodontium
- Gingiva
- Gingival phenotype
- Cone beam CT
- Alveolar bone loss

In the PubMed database, these terms were applied in four different search combinations to refine the results and capture relevant studies:

- (“Periodontium” [Mesh]) AND “Cone-Beam Computed Tomography” [Mesh]
- (“Gingiva” [Mesh]) AND “Cone-Beam Computed Tomography” [Mesh]
- ((“Gingiva” [Mesh]) AND “Cone-Beam Computed Tomography” [Mesh]) AND “Diagnosis” [Mesh]
- (((“Periodontium” [Mesh]) AND “Cone-Beam Computed Tomography” [Mesh]) AND “Diagnosis” [Mesh])

The last electronic search was conducted in May 2025. In addition, manual screening of the reference lists of included articles and relevant reviews was performed to identify potentially eligible studies.

2.2. Eligibility Criteria

2.2.1. Inclusion Criteria

Studies were considered eligible if they met the following criteria:

- Clinical observational and comparative studies evaluating cone-beam computed tomography (CBCT) in comparison to conventional clinical methods for assessing gingival and bone thickness.
- Publications dated between 2013 and 2024.
- Articles written in French, English, or Spanish.
- Clinical studies conducted on human subjects, specifically focusing on the comparative clinical and radiographic analysis of the periodontal phenotype.

2.2.2. Exclusion Criteria

The following studies were excluded:

- Articles that did not align with the objectives and inclusion criteria of this review, based on abstract screening and full-text critical analysis.
- Research lacking objective parameters for measuring soft tissue and bone dimensions.
- Randomized controlled trials that solely compared variations of the same technique.

2.3. PICO Eligibility Criteria

The selection of studies in this systematic review followed the PICO framework, considering the criteria outlined below.

2.3.1. Participants (P)

Included individuals (both men and women) with a healthy periodontium and intact anterior teeth, free from periodontal disease.

2.3.2. Interventions (I)

- Clinical assessment methods: Visual examination, probe transparency evaluation, ultrasound, and transgingival probing.
- CBCT analysis: Used for measuring the thickness of both soft and hard tissues.

2.3.3. Comparisons (C)

All possible comparisons among the selected interventions were analyzed.

2.3.4. Outcomes (O)

The evaluation criteria included:

- Gingival biotype classification: Defined as either thin or thick based on periodontal probe visibility through the gingival tissue (visible = thin, not visible = thick) or determined via transgingival probing or ultrasound.
- Bone thickness and height: Assessed using CBCT.
- Gingival and bone thickness measurements: Taken for each tooth, using the cemento-enamel junction (CEJ) as a reference on the buccal-lingual axis, perpendicular to the tooth's sagittal plane.

2.4. Quality Assessment and Risk of Bias

The quality assessment focused on key methodological aspects, including randomization, allocation concealment, blinding of participants and clinicians, blinding of evaluators, and the completeness of follow-up.

Based on these criteria, studies were categorized as follows:

- Low risk of bias: When all three quality criteria were satisfied.
- Unclear risk of bias: When one or more criteria were only partially met.
- High risk of bias: When at least one of the three criteria was not fulfilled.

This evaluation was carried out independently and in triplicate by three authors (O.B.M., A.Kh., and B.S.).

Although several included studies were observational, the selected quality assessment framework was used to evaluate methodological rigor and potential sources of bias in a standardized manner across studies. The results should therefore be interpreted as an assessment of methodological quality rather than a formal risk-of-bias evaluation specific to randomized controlled trials.

2.5. Data Extraction

Data collection was performed independently by three reviewers (O.B.M., A.Kh., and B.S.), extracting the following information: study title, authors, year of publi-

cation, study design, sample size, outcome measures, type of intervention, study duration, clinical findings, and overall study quality.

Because of substantial heterogeneity in study design, measurement techniques, anatomical sites, and periodontal phenotype classifications, a quantitative meta-analysis was not considered appropriate. Therefore, findings were synthesized narratively.

3. Results

3.1. Study Selection

A systematic search was conducted in the MEDLINE (PubMed), ScienceDirect, Cochrane, and EBSCO host databases using Boolean keyword combinations. This search identified 89, 261, 25, and 19 articles published between 2013 and 2024, respectively.

After eliminating duplicate records and screening titles and abstracts, 29 studies remained. The application of inclusion and exclusion criteria resulted in the final selection of 11 studies for this systematic review. A flowchart was created to illustrate the study selection process (See **Figure 1**).

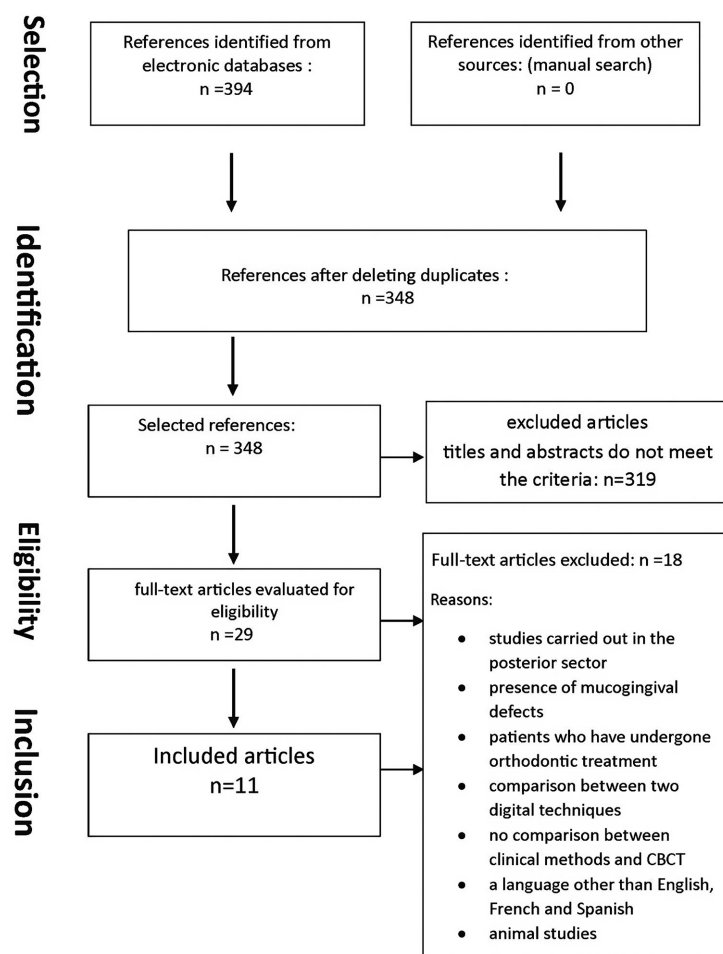


Figure 1. Flow diagram of the screening and selection process.

3.2. Study Characteristics

3.2.1. Included Studies

A total of 11 studies met the eligibility criteria for inclusion in this systematic review. The sources of funding were as follows:

- Four studies [8]-[11] received approval from their university ethics committees but did not obtain external financial support.
- Two studies [12] [13] were funded by their respective scientific research institutions.
- One study [14] was personally financed by the authors.
- Two studies [15] [16] were supported financially by their affiliated institutions.
- Two studies [17] [18] did not disclose their funding sources.

3.2.2. Excluded Studies

18 studies were excluded based on the following reasons:

- Comparison of two different digital evaluation techniques.
- Lack of clinical measurement methods for validation against CBCT data.
- Study population included orthodontic patients.
- Focus exclusively on the posterior dental region.
- Participants had periodontal defects, such as gingival recessions or bone fenestrations.
- Animal studies.
- Publications in Chinese.
- Full-text versions were not available for data extraction.

3.3. Risk of Bias in Included Studies

An assessment of study quality determined that six out of the 11 included studies [8] [9] [12]-[14] [16] had a low risk of bias. A detailed summary of the risk of bias evaluation is presented in **Table 1**.

Table 1. Risk of bias in the studies.

Study	Randomization	Secret assignment	Blinded procedure	Risk of bias
Falabella MV <i>et al.</i> , 2021 [17]	appropriate	inadequate	No	high
Kim YJ <i>et al.</i> , 2021 [18]	appropriate	inadequate	No	high
Younes F <i>et al.</i> , 2016 [14]	appropriate	inadequate	No	low
Bednarz-Tumidajewicz M <i>et al.</i> , 2022 [8]	appropriate	appropriate	No	low
Das G <i>et al.</i> , 2022 [12]	appropriate	appropriate	No	low
Shao Y <i>et al.</i> , 2018 [9]	appropriate	appropriate	No	low
Frost NA <i>et al.</i> , 2015 [13]	appropriate	appropriate	No	low
Khoury J <i>et al.</i> , 2016 [15]	appropriate	inadequate	No	high
Nisanci Yilmaz MN <i>et al.</i> , 2022 [10]	inadequate	inadequate	No	high
Chanmanee P <i>et al.</i> , 2019 [16]	appropriate	appropriate	No	low
Frumkin N <i>et al.</i> , 2017 [11]	appropriate	inadequate	No	high

3.4. Analysis Results

Clinical data from the 11 selected studies, comprising a total of 540 patients, were analyzed in this systematic review. The studies were categorized based on the PICO framework: Participants/Intervention (**Table 2**) and Comparison/Outcomes (**Table 3**).

Table 2. PICO criteria for participants/interventions to determine periodontal biotype (Clinical methods/CBCT).

General description		1st criteria: PATIENTS		2nd Criteria: INTERVENTIONS	
Type of study	Year	Number of patients	Teeth examined	Clinical methods	CBCT
Kim YJ <i>et al.</i> [18]					
Randomized Controlled Trial	2021	20	Maxillary anterior teeth	Transparency of the periodontal probe	Gingival and bone thickness taken at different levels: GT0; GT1-GT5; BT1-BT5
Falabella MV <i>et al.</i> [17]					
Transversal study	2021	60	Maxillary anterior teeth	Transparency of the periodontal probe	Thickness of gingiva and bone taken perpendicular to the long axis of the tooth: BT/GT1; BT/GT3
Bednarz-Tumidajewicz M <i>et al.</i> [8]					
Randomized Controlled Trial	2022	30	Maxillary anterior teeth	ultrasonography Thickness of gingiva at different levels: FGTu; SGTu; CGT	Thickness of gingiva at different levels: FGTct; SGTct; CGTct
Younes F <i>et al.</i> [14]					
Randomized Controlled Trial	2016	21	Maxillary anterior teeth	ultrasonography	Bone thickness taken from BT1 to BT5
Das G <i>et al.</i> [12]					
Cross-sectional descriptive study	2022	200	The two maxillary central incisors (11/21)	Trans-gingival probing	GT measurements were taken at different apico-coronal levels.
Shao Y <i>et al.</i> [9]					
Transversal study	2018	31	Maxillary and mandibular anterior teeth	-Transgingival probing (GTp). -Transparency of the periodontal probe Williams probe (Hu-Friedy, IL, USA)	GT and BT measurements were taken at different levels.
Frost NA <i>et al.</i> [13]					
Transversal study	2015	56	Maxillary anterior teeth	-Transparency of the periodontal probe -Transgingival probing	BT taken at 1 mm apical to the alveolar crest
Khoury J <i>et al.</i> [15]					
Transversal study	2016	47	Maxillary anterior teeth	Transparency of the periodontal probe (Hu-Friedy)	BT taken at different levels: BT4 - BT10 and JEC-BT
Nisanci Yilmaz MN <i>et al.</i> [10]					
Transversal study	2022	Not reported (86 teeth)	Maxillary anterior teeth	-Transparency of the periodontal probe (CBP; Hu-Friedy, Chicago, IL); -Trans-gingival probing	Buccal bone and gingival tissue thicknesses at GT1 and BT1

Continued

Chanmanee P <i>et al.</i> [16]					
Transversal study	2019	40 patients (240 teeth)	Maxillary anterior teeth	Transparency of the periodontal probe	GT and bone thickness at BT2 - BT4.
Frumkin N <i>et al.</i> [11]					
Prospective Interventional Study	2017	35 patients	Maxillary and mandibular teeth	Transparency of the periodontal probe (color-coded probe 15 UNC, Hu-friedy).	BT measurements were taken on teeth at different levels: BT to AC; BT to AD

TRAN: periodontal probe transparency; **BT:** bone thickness; **GT:** gingival thickness; **GT0:** gingival thickness at the alveolar ridge line, **GT1-GT5:** gingival thickness from 1 to 5 mm below the alveolar ridge; **BT1-BT5:** alveolar bone thickness from 1 to 5 mm below the alveolar ridge by CBCT; **BT/GT1:** 1 mm above the alveolar bone crest by CBCT; **BT/GT3:** 3 mm above the alveolar bone crest by CBCT; **FGT:** free gingival thickness; **GTu:** gingival thickness measured by ultrasound; **FGTu:** the distance between the gingival margin and the bottom of the gingival sulcus by ultrasound; **SGT:** supracrestal gingival thickness; **SGTu:** measured at a point 1 mm apically from the enamel-cement junction by ultrasound; **CGT:** crestal gingival thickness; **CGTu:** at a distance of 1 mm from the edge of the alveolar bone by ultrasound; **FGTct:** free gingival thickness measured at the midpoint between the gingival margin and the bottom of the gingival sulcus by CBCT; **SGTct:** Supracrestal gingival thickness measured at the point 1 mm apically from the enamel-cement junction by CBCT; **CGTct:** Crestal gingival thickness at a distance of 1 mm from the edge of the alveolar bone by CBCT; **BT4-BT10:** buccal bone thickness at 4, 6, 8 and 10 mm apical to the JEC by CBCT; **JEC-BT:** distance between JEC and bone crest by CBCT; **GT1:** gingival thickness at 1 mm apical to the gingival margin by CBCT; **BT1:** bone thickness at 1 mm apical to the bone crest by CBCT; **BT2-BT4:** bone thickness from crestal bone level to 2 mm and 4 mm apically by CBCT; **WKT:** width of keratinized tissue; **GTp:** gingival thickness measured by transgingival probing; **GTct:** gingival thickness measured by CBCT; **BT from JEC to alveolar crest (AC);** and **Width of vestibular cortex at alveolar crest,** and **JEC -apex distance (AD),** and **Width of vestibular cortex at tooth apex** (measured from root center) by CBCT.

Table 3. PICO Comparison and Results criteria for determining periodontal biotype.

3rd criteria: COMPARISONS		4th criteria: RESULTS						
Periodontal biotype	Clinical methods				CBCT			p-value
	Trans-gingival probe	Probe transparency	Ultrasound	Gingival thickness	Bone thickness			
Das G <i>et al.</i> 2022 [12] Pakistan								
200 patients	Thin biotype	Right incisor (11) 0.99 ± 0.17 57%	NR*	NR*	Right incisor (11) 1.04 ± 0.18		NR*	0.130 0.37
		Left incisor (21) 1.09 ± 0.25 44%			Left incisor (21) 1.14 ± 0.28			
		Right incisor (11) 1.31 ± 0.18 43%			Right incisor (11) 1.34.99 ± 0.17			
	Thick biotype	NR*	NR*	NR*		0.429 0.133		
							Left incisor (21) 1.22 ± 0.21 56%	Left incisor (21) 1.22 ± 0.21
Kim YJ <i>et al.</i> 2021 [18] South Korea								
20 patients	Thin biotype	NR*	TRAN 0 40%	NR*	GT0 1.38 ± 0.32 GT1-GT5 0.96 ± 0.36	BT1-BT5	0.79 ± 0.20	0.028 0.396
	Thick biotype	NR*	TRAN 1 60%	NR*	GT0 1.72 ± 0.25 GT1-GT5 0.88 ± 0.17	BT1-BT5	0.77 ± 0.17	0.908
Beire JM <i>et al.</i> 2021 [17] Brazil								
60 patients	Thin biotype	NR*	26.7% WKT = 4.90 mm	NR*	GT1 (11) 0.65 ± 0.15 GT3 (11) 0.57 ± 0.20	BT1 (11) BT3 (11)	0.88 ± 0.16 0.85 ± 0.13	0.30 0.75
	Thick biotype		73.3% (percentage by gender (H/F)) 5.46 mm					

Continued

	Thin biotype		26.7% (percentage by gender (H/F))							
	Scalloped thick biotype	NR*	4.70 mm 55.0% 5.27 mm 18.3% thick biotype flat 6.04 mm	NR*	GT1 (21) 0.56 ± 0.22 GT3 (21) 0.54 ± 0.24	BT1 (21) BT3(21)	0.87 ± 0.18 0.85 ± 0.20	0.01 0.64		
Bednarz-Tumidajewicz M <i>et al.</i> 2022 [8] Poland										
30 patients	Biotype thin 11.67%	NR*	NR*	FGTu	0.60 ± 0.69	FGTct	0.60 ± 0.70	0.000		
				CGTu	0.72 ± 1.00	SGTct	1.25 ± 1.58	0.009		
				SGTu	0.47 ± 0.72	CGTct	0.67 ± 0.92	0.823		
	Medium biotype47.22%			FGTu	0.82 ± 0.94	FGTct	0.80 ± 0.90	0.001		
				SGTu	0.93 ± 1.27	SGTct	1.45 ± 1.80	0.001	NR*	
				CGTu	0.61 ± 0.76	CGTct	0.70 ± 1.00	0.125		
	Thick biotype 41.11%			FGTu	1.06 ± 1.35	FGTct	1.10 ± 1.23	0.000		
				SGTu	0.98 ± 1.37	SGTct	1.80 ± 2.23	0.000		
				CGTu	0.62 ± 0.77	CGTct	0.90 ± 1.25	0.000		
Younes F <i>et al.</i> 2016 [14] Belgium										
21 patients	NR*	NR*	NR*	0.76 ± 1.92	NR*	BT1	0.97 ± 0.28	0.025		
						BT2	1.10 ± 0.38			
						BT3	1.10 ± 0.43			
						BT4	1.10 ± 0.41			
						BT5	1.08 ± 0.43			
Shao Y <i>et al.</i> 2018 [9] China										
31 patients	Thick-flap biotype: 137 teeth (36.83%)	Maxilla GTp: 1.21 ± 0.27 mm	In a set of 372 teeth, 222 (59.68%) had thick gingiva at probe transparency, while 150 (40.32%) had thin gingiva	NR*		Maxilla GTct: 1.21 ± 0.25 mm	Maxilla BT: 0.73 ± 0.22 mm Mandible BT: 0.60 ± 0.17 mm	0.051		
	Medium split biotype: 96 teeth (25.81%)	11/21				Mandible GTct: 0.94 ± 0.21 mm				
	Medium-flap biotype: 39 teeth (10.48%)	Mandible GTp: 0.85 ± 0.24 mm				average of GTct: 1.03 ± 0.24 mm				
	Biotype with fine slit: 100 teeth (26.88%)	1.03 ± 0.31 mm, 31/41				Thin gingiva: 18.55%				
		0.89 ± 0.23*				Thick gingiva: 81.45%				
Frost NA <i>et al.</i> 2015 [13] USA										
56 patients	Thick biotype: 83%	NR*	Thick biotype: 1.02 ± 0.28 mm	NR*	NR*	Thick biotype: 0.805 ± 0.364 mm	<0.001	0.06		
	Thin biotype: 17%		Thin biotype: 0.17 ± 0.25 mm			Thin biotype: 0.21 ± 0.429 mm				
Khoury J <i>et al.</i> 2016 [15] Lebanon										
47 patients	Thick biotype 40% (84 Teeth)	NR*	Thick biotype: (>1 mm) thin biotype: (≤1 mm)	NR*	NR*	Distance BT/JEC To:	<0.0001			
	thin biotype: 60% (126 Teeth)					- 4 mm:				
						thick				0.472
	thin					0.388				
	- 6 mm:									
						thick				0.525
	thin					0.373				
	- 8 mm:									
						thick				0.612
	thin					0.414				
- 10 mm:										
	thick	0.620								
thin	0.497									
Nisanci Yilmaz MN <i>et al.</i> 2022 [10] Turkey										
not reported (86 Teeth)	Thin to medium biotype	0.64 ± 0.08 mm	0.85 mm	NR*	Average gingival thickness is 1.31 ± 0.43 mm	Mean buccal bone thickness at 1 mm apical to the crest was 0.71 ± 0.25 mm.	p < 0.001			
	Medium to thick biotype	1.06 ± 0.1 mm	1.23 mm							
	Thick to very thick biotype	1.35 ± 0.1 mm	1.53 mm							

Continued

Chanmanee P <i>et al.</i> 2019 [16] Thailand						
40 patients (240 Teeth)	Thick gingival biotype (108 teeth)	NR*	-Thick biotype = no probe visibility	NR*	Buccal gingiva thickness is 0.23 ± 0.33 mm	Thick biotype: 0.41 ± 0.54 mm
	Thin gingival Biotype (132 teeth)		-Thin biotype = visibility of probe through soft tissue.		Palatal gingival thickness is between 0.48 ± 0.52 mm	Thin biotype: 0.32 ± 0.46 mm
Frumkin N <i>et al.</i> 2017 [11] Israel						
35 patients	Thin biotype: 63 patients	NP*	-Thin biotype: probe transparency = positive	NR*	NR*	(21)PPT/NPT: Distance: 3.96 ± 1.18/ -JEC-crest 4.14 ± 1.77 -Bone width 1.15 ± 0.37/ at crest level 1.06 ± 0.31 -JEC-apex 12.20 ± 1.87/ -apical bone 12.16 ± 2.04 width 1.59 ± 0.66/ 2.06 ± 0.44
	Thick biotype: 37 patients		-Thick biotype: probe transparency = negative			Not significant except for (13) p = 0.026

p < 0.05: statistically significant difference between groups; **p > 0.05:** statistically non-significant difference between groups. **NR*:** not reported; **TRAN:** periodontal probe transparency; **BT:** bone thickness; **GT:** gingival thickness; **FGT:** free gingival thickness; **SGT:** supracrestal gingival thickness; **CGT:** crestal gingival thickness; **WKT:** width of keratinized tissue; **GTu:** gingival thickness measured by ultrasound; **GTp:** gingival thickness measured by transgingival probing; **GTct:** gingival thickness measured by CBCT; **PPT:** positive probe transparency; **NPT:** negative probe transparency.

Main Findings:

- A statistically significant correlation was observed between transgingival probing and CBCT in measuring gingival biotype thickness [9] [10] [12].
- No significant correlation was found between periodontal probe transparency and CBCT measurements [9] [13].
- A positive correlation was reported between gingival thickness at the bone crest and the vestibular alveolar bone cortical thickness [10] [13] [14] [18].
- Some studies noted a significant negative correlation between gingival and bone thickness when measured 1 to 3 mm above the bone crest [17].
- The thick periodontal phenotype was predominant in both sexes, with no statistically significant difference ($p > 0.05$) [17].
- Patients with a thick biotype exhibited greater buccal bone thickness than those with a thin biotype, across all maxillary anterior teeth and measurement levels. This difference was highly significant ($p < 0.0001$), suggesting a strong association between a thick biotype and increased underlying bone thickness [15].
- No significant difference was found in the positioning of maxillary incisors between different biotypes [16].
- Buccal and palatal gingival thickness gradually increased toward the apical region in both biotypes [16].
- Individuals with a thick biotype demonstrated increased gingival thickness in the vestibular attached gingiva, while vestibular bone thickness remained comparable between biotypes [16].
- Intra-individual variations in biotypes were noted within the same jaw, depending on the specific region analyzed [11].
- A comparative analysis of three gingival phenotypes (thin, medium, and thick)

using CBCT revealed statistically significant differences across all examined variables ($p < 0.000$), confirming that gingival thickness, as assessed by CBCT, varies significantly among different phenotypes.

4. Discussion

This systematic review evaluated the reliability and reproducibility of cone-beam computed tomography (CBCT) compared to conventional clinical methods for assessing gingival and alveolar bone thickness. Based on 11 cross-sectional studies involving a total of 540 patients, the objective was to explore the relationship between gingival phenotype and bone thickness to refine the characterization of periodontal biotypes.

Several clinical techniques were employed to measure soft tissue thickness, including periodontal probe transparency, transgingival probing using an endodontic file, and ultrasonography. From a radiographic perspective, CBCT was utilized to assess bone thickness and height at different levels along the dental roots.

The findings demonstrated a general positive correlation between gingival thickness and alveolar bone thickness, though some studies reported inconsistencies. One limitation of CBCT is its lower resolution for soft tissue imaging. To address this issue, techniques such as the use of radiopaque markers and lip retractors have been suggested to enhance image clarity.

Analysis of the collected data indicated a notable increase in cortical bone thickness among individuals with a thick gingival phenotype. These findings support the use of CBCT as a valuable adjunct to clinical assessment for accurately determining the periodontal biotype. A combined approach integrating both methods enhances treatment planning for periodontal, orthodontic, and implant procedures, ultimately improving both functional and aesthetic outcomes.

4.1. The Concept of Periodontal Phenotype

The term *periodontal phenotype*, introduced in the 2018 classification of periodontal and peri-implant diseases, describes the relationship between gingival characteristics (thickness and height) and bone morphotype [2]. Evaluating this parameter is essential for optimizing treatment outcomes in periodontal plastic surgery, orthodontics, implantology, and prosthodontics.

The distinction between *biotype* and *phenotype* provides a clearer understanding of the interactions between soft and hard tissues. Gingival thickness, the width of keratinized tissue, and bone morphology all play a crucial role in susceptibility to mucogingival defects, such as gingival recession [13]. A thin gingival profile is frequently associated with reduced bone thickness, increasing the likelihood of recessions and reducing tissue resilience during clinical procedures [2] [13].

A systematic review by Amid *et al.* (2020) [19] highlighted that patients with a thin gingival biotype have a greater risk of developing gingival recessions following orthodontic treatment. Additional studies have confirmed that a thin phenotype (average gingival thickness of 0.80 mm) is linked to thinner vestibular bone

(0.343 mm), whereas a thicker biotype (>1 mm) demonstrates greater resistance to mechanical and surgical interventions [4] [6].

Several factors influence the periodontal biotype, including dental positioning (teeth located more vestibularly tend to have thinner gingiva), age (younger adults often present with thinner tissues), gender (men generally have thicker gingiva), ethnic background, and anatomical location (gingival tissue is typically thicker in the maxilla) [9] [15]. These factors should be carefully considered when planning treatments.

Assessing the periodontal phenotype before any intervention is essential to prevent complications. Patients with a thick phenotype and no signs of recession require routine monitoring, whereas those with a thin phenotype necessitate closer observation. In cases where the gingival tissue is exceptionally thin, mucogingival surgery may be recommended to strengthen the periodontium before initiating orthodontic or implant procedures [1].

4.2. Clinical Analysis of Gingival Phenotype

The gingival phenotype plays a crucial role in dental treatment planning, significantly impacting both clinical outcomes and aesthetics. Insufficient gingival thickness around natural teeth has been linked to a higher risk of recession following initial therapy and an increased likelihood of unsuccessful root coverage. Research suggests that a minimum gingival thickness of 0.8 mm to 1 mm is necessary for effective root coverage in cases of recession [1]. Thin gingival biotypes are more prone to recession, which can weaken the periodontium and complicate orthodontic, implant, or prosthetic procedures [1] [20].

Various methods are available for measuring gingival thickness, broadly categorized into invasive and non-invasive techniques.

4.2.1. Invasive Clinical Methods

Transgingival probing is considered the gold standard for assessing gingival thickness. This method involves inserting an endodontic file through the gingiva until it reaches the root surface or alveolar bone. The thickness is determined by measuring the distance from the tip of the file to a silicone marker. While highly precise (± 0.5 mm), this technique is invasive and may cause temporary patient discomfort [21]. Studies by Das G *et al.* (2022) [12] and Yilmaz MNN *et al.* (2022) [10] have demonstrated a strong correlation between transgingival probing and CBCT measurements, reinforcing its reliability in distinguishing between thin and thick biotypes.

4.2.2. Non-Invasive Clinical Methods

Periodontal probe transparency involves inserting a probe into the buccal sulcus and determining whether it is visible through the gingiva. This method classifies gingival thickness as either thin (≤ 1 mm) or thick (> 1 mm) [22]. De Rouck *et al.* [23] reported an 85% repeatability rate among examiners ($k = 0.7$, $P = 0.002$). Additionally, a color-coded periodontal probe has been introduced to categorize

biotypes into four groups: thin, medium, thick, and very thick [24]. However, studies by Shao Y *et al.* (2018) [9] and Frost NA *et al.* (2015) [13] found poor correlation between this method and CBCT-measured vestibular bone thickness, raising concerns about its diagnostic accuracy.

Ultrasonography utilizes an echo-impulse system to measure soft tissue thickness with an accuracy of 0.01 mm [14]. This technology can differentiate anatomical structures in either A-mode (one-dimensional) or B-mode (two-dimensional, high-resolution) imaging [8]. Research by Eghbali *et al.* (2014) [25] supports its effectiveness in assessing gingival thickness, provided minimal pressure is applied to the transducer probe. However, some limitations exist, including a weak correlation with transgingival probing ($r = 0.32$) as reported by Younes *et al.* (2016) [14]. Additionally, its applicability in posterior regions is restricted due to the transducer's 3 mm diameter, which reduces measurement precision [26].

Accurate evaluation of gingival phenotype is essential for planning various dental treatments. While invasive techniques provide precise measurements, they may cause discomfort for patients. On the other hand, non-invasive methods, although promising, still require further refinement to ensure consistent reliability, particularly in complex anatomical areas. The integration of advanced non-invasive tools, such as high-resolution ultrasonography, holds potential for improving clinical diagnostics while enhancing patient comfort. Continued research is needed to optimize these technologies, enabling more precise and personalized periodontal and implant treatments.

4.3. Radiographic Analysis of Periodontal Morphotype

The classification of bone morphotype, first introduced by Becker *et al.* (1997) [27], distinguishes three primary forms: flat, scalloped, and pronounced scalloped. Some researchers also categorize it based on alveolar cortical thickness, considering both buccal and palatal aspects.

Cone-beam computed tomography (CBCT) has become a fundamental imaging technique for implant planning and evaluating both bone and gingival structures. This technology facilitates the assessment of mucosal and gingival thickness while also identifying bone deficiencies, particularly in the context of immediate implant placement [28] [29]. CBCT is favored over conventional tomography due to its lower cost, reduced radiation exposure, and greater ease of use [30].

Despite utilizing ionizing radiation, CBCT is widely regarded as a precise and non-invasive diagnostic tool. Studies have confirmed its high accuracy, with linear measurement precision reaching 0.0864 mm [31]. However, factors such as resolution, field of view, and voxel size can influence measurement reliability [32] [33].

One limitation of CBCT is its reduced resolution for soft tissues. To enhance accuracy in gingival assessment, complementary approaches such as radiopaque markers and lip retractors have been suggested. Research, including a study by Silva JNN *et al.* (2017) [34], has demonstrated a significant correlation between bone and gingival thickness ($p \leq 0.020$), with a strong alignment between CBCT

data and invasive clinical methods ($p \leq 0.001$).

Bone morphology is a crucial factor across various dental specialties. Studies like that of Kalina *et al.* (2021) [35] highlight the importance of considering bone morphotype to prevent complications such as bone loss or dehiscence and to enhance treatment success.

Research has consistently shown a positive correlation between a thick gingival phenotype and greater cortical bone thickness. However, this association can vary depending on tooth location and measurement site. General trends indicate that:

- Thin gingival biotypes are more frequently observed in the maxilla (Frumkin *et al.*, 2017) [11].
- In the mandible, thinner gingiva is associated with a higher risk of gingival recession (Kim *et al.*, 2020) [36].

Studies by Das G *et al.* (2022) [12] and Yilmaz MNN *et al.* (2022) [23] confirm a strong correlation between CBCT measurements and transgingival probing, reinforcing its diagnostic reliability. However, some traditional clinical methods, such as probe transparency, have been questioned due to their limited precision, as noted by Shao Y *et al.* (2018) [9] and Frost NA *et al.* (2015) [13].

CBCT plays a pivotal role in accurately assessing periodontal dimensions, reducing variability in clinical measurements. While routine use may not always be justified due to radiation exposure, it remains a critical tool for implant, orthodontic, and prosthetic treatment planning [37]. A combined approach integrating CBCT with traditional clinical techniques offers an optimal balance between precision, cost-effectiveness, and patient comfort.

4.4. Clinical Implications

The accuracy of periodontal tissue measurements varies depending on the method used. Transgingival, ultrasonographic, and radiographic techniques provide approximate values that are influenced by the instruments employed. Kloukos *et al.* [38] demonstrated that sharp instruments overestimate gingival thickness by 22% compared to blunt probes, highlighting the need for methodological standardization to improve the comparability of results.

A thin periodontal biotype, which is marked by reduced gingival and bone thickness, significantly increases the likelihood of gingival recession. Although a minimum of 2 mm of keratinized tissue and 1 mm of attached gingiva is recommended for maintaining periodontal health, proper oral hygiene remains a crucial factor in preventing recession. During orthodontic treatment, tooth movement can aggravate this condition, with reported prevalence rates ranging from 5% to 12% [39]-[41]. When gingival thickness is less than 2 mm, the risk of recession is heightened, and in some cases, gingival grafting may be required before proceeding with orthodontic or other treatments.

Several methods are available for evaluating gingival thickness, one of which involves observing the visibility of a probe through the gingiva. Pontoriero and Carnevale [42] found that patients with a thicker biotype experienced better tissue

recovery after coronal lengthening. Hwang and Wang [43] suggested a minimum thickness of 1.1 mm for ensuring complete root coverage, while Zuhr *et al.* [44] concluded that a thickness greater than 1.44 mm ensures more stable tissue after surgery.

For patients with a thin biotype, a customized approach may be necessary, especially in cases involving aesthetic concerns, hypersensitivity, cervical lesions, or restorations in the sulcus. In such situations, muco-gingival surgery may be indicated, particularly as an adjunct to orthodontic or implant treatments.

4.5. Limitations of the Study

This review has some limitations, including heterogeneity among studies regarding dental regions, measurement levels, CBCT protocols, and phenotype classifications. In addition, several studies included relatively small sample sizes, which may limit the generalizability of the findings.

In conclusion, while there is a moderate correlation between gingival and bone thickness, a clear distinction exists between thin and thick gingival phenotypes, with thicker gingiva generally associated with greater alveolar bone thickness. Assessing probe visibility may serve as a useful and simple clinical indicator for estimating bone morphology and supporting orthodontic or implant treatment planning.

The available evidence suggests that CBCT is a valuable adjunctive tool for measuring gingival thickness in both anterior and posterior regions and for characterizing the periodontal phenotype. Several studies reported good agreement between CBCT measurements and transgingival probing; however, the current evidence is mainly derived from heterogeneous observational studies. Ultrasound appears accurate for anterior measurements but may have limitations in posterior regions.

Future studies using standardized measurement protocols and larger sample sizes are needed to strengthen the evidence and improve the clinical assessment of periodontal phenotype.

Funding

This study was self-funded by the authors.

Acknowledgements

Our acknowledgment goes to all those who contributed to this document.

Conflicts of Interest

The authors declare no competing interests.

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