Received: 12 June 2020 | Revised: 10 August 2020 | Accepted: 4 September 2020
DOI: 10.1111/jerd.12661

REVIEW ARTICLE

WILEY

Periodontal phenotype: A review of historical and current classifications evaluating different methods and characteristics

Violeta Malpartida-Carrillo DDS, MSc[1] | Pedro Luis Tinedo-Lopez DDS, MSc[1] | Maria Eugenia Guerrero DDS, PhD[2] | Silvia P. Amaya-Pajares DDS, MSc[3] | Mutlu Özcan DDS, PhD[4] | Cassiano Kuchenbecker Rösing DDS, PhD[5]

[1]Department of Periodontology, School of Stomatology, Universidad Privada San Juan Bautista, Lima, Peru

[2]Medico Surgical Department, Faculty of Dentistry, Universidad Nacional Mayor de San Marcos, Lima, Peru

[3]Department of Restorative Dentistry, School of Dentistry, Oregon Health and Science University, Portland, OR

[4]Center of Dental Medicine, Division of Dental Biomaterials, Clinic for Reconstructive Dentistry, University of Zurich, Zurich, Switzerland

[5]Department of Periodontology, School of Dentistry, Federal University of Rio Grande do Sul, Porto Alegre, Brazil

Correspondence
Violeta Malpartida-Carrillo, School of Stomatology, Universidad Privada San Juan Bautista, 302-304 Jose Antonio Lavalle Avenue, Chorrillos, Lima-Perú.
Email: viletayu_30@hotmail.com

Abstract

Objective: To review the historical and current periodontal phenotype classifications evaluating methods and characteristics. Moreover, to identify and classify the methods based on periodontal phenotype components.

Overview: Several gingival morphology studies have been frequently associated with different terms used causing confusion among the readers. In 2017, the World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions recommended to adopt the term "periodontal phenotype". This term comprises two terms, gingival phenotype (gingival thickness and keratinized tissue width) and bone morphotype (buccal bone plate thickness). Furthermore, gingival morphology has been categorized on "thin-scalloped", "thick-scalloped" and "thick-flat" considering the periodontal biotype. However, by definition, the term phenotype is preferred over biotype. Periodontal phenotype can be evaluated through clinical or radiographic assessments and may be divided into invasive/non-invasive (for gingival thickness), static/functional (for keratinized tissue width), and bi/tridimensional (for buccal bone plate thickness) methods.

Conclusions: "Thin-scalloped," "thick-scalloped," and "thick-flat" periodontal biotypes were identified. These three periodontal biotypes have been considered in the World Workshop but the term periodontal phenotype is recommended. Periodontal phenotype is the combination of the gingival phenotype and the bone morphotype. There are specific methods for periodontal phenotype evaluation.

Clinical significance: The term periodontal phenotype is currently recommended for future investigations about gingival phenotype and bone morphotype. "Thin-scalloped," "thick-scalloped," and "thick-flat" periodontal phenotypes can be evaluated through specific methods for gingival thickness, keratinized tissue width, and buccal bone plate thickness evaluation.

KEYWORDS
implants, periodontics, periodontics/prosthodontics, radiology

1 | INTRODUCTION

In the current era of esthetic-driven dentistry it is of utmost importance to be aware of all the factors that can influence the final esthetic result of a treatment. One of the most important factors is the diagnostic assessment of soft and hard tissues around the teeth, which will have substantial importance in the decision-making process for periodontal, restorative, prosthetic, orthodontic, and implant treatment.[1-3]

The term "gingival biotype" has been commonly used to describe the gingiva in the bucco-lingual dimension,[4] whereas the terms "periodontal biotype,"[5] "periodontal morphotype," "gingival morphotype,"[6] and "gingival phenotype"[3,7] not only refer to clinical variations in the gingival thickness (GT) and keratinized tissue width (KTW), but also to other characteristics, such as bone morphotypes, tooth shape, and morphological characteristics of the gingiva and the periodontium.[4,8] The 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions recommended the adoption of the term "periodontal phenotype,"[9] although another report of this World Workshop used the term "periodontal biotype" to analyze the mucogingival conditions in the natural dentition.[10] Based on this World Workshop, "periodontal phenotype" describes the combination of gingival phenotype (three-dimensional gingival volume) and bone morphotype. Reportedly, gingival phenotype is constituted by GT and KTW, whereas bone morphotype, by the buccal bone plate thickness (BBPT).[9]

Periodontal phenotypes may respond differently to inflammation, surgical, and restorative procedures since it is observed that both gingival and bone thicknesses may affect the final outcome of the treatment. Several hypotheses have been raised in an attempt to explain this situation, including difference in the amount of blood supply to the underlying bone[11] and resorption susceptibility.[12] In addition, it is generally accepted that a thin periodontal phenotype is associated with unfavorable treatment outcomes after surgical interventions. Furthermore, in patients with thin GT, in most situations, additional procedures are necessary while in situations with thicker tissues, a straightforward approach can be chosen.[13] Accordingly, special care should be taken in early diagnosis and treatment planning for patients with a thin periodontal phenotype.

It is interesting to notice that the recent World Workshop recommended to evaluate periodontal phenotype in a standardized and reproducible way, for example, with the aid of a periodontal probe to measure the GT. To accomplish this, is necessary to observe the periodontal probe by transparency through the gingival tissue after being inserted into the sulcus. Thus, it is assumed that the probe will be visible when GT is thin (≤1 mm) and not visible in a thick GT (>1 mm).[9] On the other hand, another report of the World Workshop[10] categorized the periodontal biotype on "thin-scalloped," "thick-scalloped," and "thick-flat" patterns. Such definitions are based in a systematic review about periodontal biotype,[10] similar to previous studies that reported two extreme and one in-between cluster.[7,14,15] However, although some methods to discriminate thin or thick gingival phenotype were described,[1,4,16] there is a lack of knowledge about which methods can be used to evaluate periodontal phenotypes, especially in a clinical setting.[8-10]

In the light of different confusing definitions and several methods of evaluation reported, adequate knowledge is required for the sake of familiarity by dental practitioners with recent major updates about periodontal phenotype to gear knowledge toward optimum early diagnosis of patients.

Hence, the objective of the present work is to review historical and current periodontal phenotype classifications, characteristics, and considerations reported in the literature. Moreover, to identify and classify the methods for evaluation of periodontal phenotype components (GT, KTW, and BBPT).

2 | HISTORICAL AND CURRENT CLASSIFICATIONS, CHARACTERISTICS, AND CONSIDERATIONS ABOUT PERIODONTAL PHENOTYPE

Periodontal anatomical characteristics have been studied for approximately one century. Probably Hirschfield[17] was the precursor in 1923, studying dry human skulls of the American Museum of Natural History looking at periodontal breakdown and reported several findings related to differences in the alveolar bone investment. In 1940, one key factor to further investigations in crown characteristics was the Wheeler´s observations[18] that identified special characteristics in the apical third of extracted teeth. In addition, aspects related to interdental alveolar bone were studied in radiographs with special interest in the position of the cementoenamel junction (CEJ).[19] From those studies, investigations looked also to soft tissues and, looking at the gingival margin position, suggested that a greater buccal prominence of tooth surface may condition a more apical position of the gingival margin.[20] Later, O´Connor and Biggs[21] studied maxillary and mandibular dry humans skulls and stated that the interproximal bone in the anterior region was predominantly convex, whereas in the posterior region was predominantly flat.

In the late 1960s, early descriptions of the gingival characteristics expanded based on the work of Ochsenbein and Ross[22] who reported the association between gingival anatomy and the underlying bone. Concurrently, these authors identified the "pronounced scalloped" and "flat" gingival anatomies. However, in 1977, Weisgold[23] described in detail "thin-scalloped" and "thick-flat" gingival architectures considering crown convexities and contact areas, as well as the periodontium and the association between the form and the function. The link between the periodontal phenotype studies and the GT gained momentum with the Claffey and Shanley´s investigation[24] about the relationship between the gingiva and bleeding on probing following non-surgical periodontal therapy. These authors addressed the transgingival probing method with the use of a stainless-steel wire for the bucco-lingual GT measurement (thin or thick).

In 1989, periodontal biotype term was coined by Seibert and Lindhe[5] who classified the periodontium into "thin-scalloped" and "thick-flat" biotypes. The first was associated with narrow zones of keratinized gingiva and slender teeth, whereas the latter was associated with wide zones of keratinized gingiva and quadratic teeth.

For the purpose of the present study, we divided the time line in four Eras of periodontal phenotype. Table 1 provides information from the First Era (1923-1989) with the main studies reporting the aforementioned classifications, characteristics, and considerations about the periodontal phenotype.

After the identification and description of two basic types of periodontal biotype, second era of periodontal phenotype (1991-1998) prompted the investigation of relationship between tooth dimensions and periodontal characteristics considering clinical evaluation, photographs, transgingival probing (syringe needle), and study casts.[6,25] Importantly, Olsson et al.[6] defined specific characteristics of a "thin-scalloped" and "thick-flat" biotype when the relationship between crown form and clinical features of the gingiva in adolescents was studied. More relevant for future studies addressed in periodontal phenotype was the inclusion of GT and KTW parameters,[6] as well as the dentogingival complex measurement from the free gingival margin to the osseous crest.[26] Furthermore, the mucoperiosteal flap thickness,[27] and the soft tissue thickness,[28] were considered for guided tissue regeneration with a threshold of 1 or 0.5 mm to consider thin or thick tissues.

In 1997, one innovative information at the time was the alveolar bone anatomical morphotypes proposed by Becker et al.[29] These authors evaluated the relationship of alveolar bone morphology with tooth form in dry human skulls considering the measurement from the interdental bone to the alveolar buccal crest. Thus, they demonstrated the existence of three bone morphologic types named flat (2 mm), scalloped (3 mm) and pronounced scalloped (4 mm). It was also with this new concept that Muller and Eger,[7] identified three gingival

TABLE 1 Characteristics of classification possibilities in the First Era of periodontal phenotype: 1923-1989

Autor (year)	Study object/ subject	Method of evaluation	Classifications, characteristics, and considerations about periodontal phenotype
Hirschfield (1923)[17]	Dry human skulls	Clinical autopsy	A thin alveolar bone contour is probably covered with a thin gingival form. The buccal (or lingual) alveolar crest is flat if the contiguous tooth surface is flat and the gingival shapes follow the same pattern.
Wheeler (1940)[18]	Extracted Teeth	Clinical autopsy	Cervical ridge in the apical third of all crowns (at the CEJ) is about 0.5 mm thicker than the tooth surface to hold the gingiva in a definite tension.
Ritchey and Orban (1953)[19]	Anterior and posterior oral radiographs	DV	The configurations of the interdental alveolar septa are determined by the relative positions of the CEJ.
Morris (1958)[20]	Oral photographs	DV	The position of the gingival margin is determined by the buccal (or lingual) prominence of the tooth surface. It is more coronal with lesser prominence and more apical with greater prominence. The degree of prominence may be influenced by tooth position, tooth shape, and bone shape.
O'Connor and Biggs (1964)[21]	Dry human skulls	Clinical autopsy	Interproximal bone in the anterior region is predominantly convex, whereas in the posterior region is predominantly flat.
Ochsenbein and Ross (1969)[22]	Patients	Clinical	Association between gingival anatomy and underlying bone. "Pronounced scalloped" type: Tapering teeth. "Flat" type: Square teeth.
Weisgold (1977)[23]	Patients	Clinical	Gingival architecture. "Thin-scalloped" type: Very subtle cervical convexities, very small contact areas and located near the incisal edge, tendency to have lees attached gingiva, thinner periodontium, and more susceptibility to recession. "Thick-flat" type: Distinct cervical convexities and broader contacts areas located more towards the gingival area. The form and function are associated.
Claffey and Shanley (1986)[24]	Maxillary and mandibular anterior and premolar regions	Clinical, transgingival stainless-steel wire	Buccolingual gingival thickness. "Thin": ≤ 1.5 mm. "Thick": ≥ 2 mm.
Seibert and Lindhe (1989)[5]			Periodontal biotype. "Thin-scalloped" type: Narrow zones of keratinized gingiva and slender teeth. "Thick-flat" type: Wide zones of keratinized gingiva and quadratic teeth.

Abbreviations: CEJ, cementoenamel junction; DV, direct vision.

phenotypes named A (normal), B (thick), and C (thin) via cluster analysis considering GT, gingival width, and the crown width/crown length ratio. These findings clearly highlighted the existence of three different gingival phenotypes related to maxillary anterior teeth and surrounding soft tissues. In the late 90s, alongside the initial descriptions of three anatomical morphotypes and three gingival phenotypes, several characteristics of the "thin-scalloped" and "thick-flat" periodontium were described, whereas "pronounced-scalloped" periodontium was little mentioned.[30] Table 2 outlines the main studies from the Second Era (1991-1998) of the aforementioned information.

From the year 2000, the Third Era of periodontal phenotype arose with investigations related to three groups of subjects with different periodontal phenotypes after the inclusion of an in-between cluster.[7] Moreover, the proposition of a simple visual method for GT evaluation based on the transparency of the periodontal probe (TRAN) through the gingival margin was emphasized.[28,31] Muller et al.[14] performed another study to confirm the results of their previous investigation[7] about periodontal phenotype and identified three clusters named A1, A2, and B. Thus, cluster A was subdivided into 2 fractions (A1 and A2) with distinct characteristics to cluster B. Subsequently, information about tissue biotype and gingival phenotype related to surgical crown lengthening[32] and associations with Schneiderian membrane thickness[33] were also documented. Technically, a key to further investigations in periodontal phenotype analysis

TABLE 2 Characteristics of classification possibilities in the Second Era of periodontal phenotype: 1991-1998

Autor (year)	Study object/subject	Method of evaluation	Classifications, characteristics, and considerations about periodontal phenotype
Olssson and Lindhe (1991)[25]	All teeth	Clinical, oral photographs	Relationship between crown form and periodontal characteristics. Long-narrow teeth showed thin biotype, length twice their width, gingival margin more apical (about 1 mm), and more recession compared to short-wide teeth.
Olsson et al. (1993)[6]	Maxillary anterior region	Clinical, transgingival syringe needle, oral photographs, study casts	Relationship between crown form and clinical features of the gingiva. Long-narrow teeth showed narrow zone of keratinized gingiva, shallow probing depth, and pronounced scalloped contour compared to short-wide teeth. No difference with respect to the thickness of the free gingiva.
Kois et al. (1994)[26]	Maxillary anterior region	Clinical	Gingival levels in relation to the restorative margin considering the DGC dimension. Measurement from the free gingival margin to the osseous crest using a periodontal probe. High osseous crest: DGC < 3 mm. Low osseous crest: DGC > 3 mm. Normal osseous crest: DGC = 3 mm.
Anderegg et al. (1995)[27]	Maxillary or mandibular molar regions	Clinical, calipers	Mucoperiosteal flap thickness. "Thin:" ≤ 1 mm. "Thick": > 1 mm.
Harris RJ. (1997)[28]	All teeth	Clinical, TRAN	Soft tissue thickness. "Thin": < 0.5 mm, possible to see the periodontal probe through the tissue. "Thick": Not possible to see the periodontal probe through the tissue.
Becker et al. (1997)[29]	Dry human skulls/Maxillary anterior region	Clinical autopsy	Alveolar bone anatomical morphotypes. Measurement from the interdental bone height to the alveolar buccal crest. "Group flat": 2.1 mm. "Group scalloped": 2.8 mm. "Group pronounced scalloped": 4.1 mm.
Müller and Eger (1997)[7]	Maxillary and mandibular anterior and premolar regions	Clinical, ultrasonic device, study casts, caliper	Gingival phenotype. "Cluster A" (Normal): Normal GT, GW (width of KT), and CW/CL. "Cluster B" (Thick): Thicker and wider gingiva, quadratic tooth. "Cluster C" (Thin): Normal GT, narrow zone of KT, quadratic tooth.
Sanavi et al. (1998)[30]			Periodontal biotype. "Thin-scalloped" and "thick-flat" types: Considerations about DGC, gingiva, crown form, contact areas, cervical convexity, interproximal papillae, underlying bone, roots, and biologic width. "Pronounced-scalloped" type only mentioned.

Abbreviations: CW/CL, crown width/crown length ratio; DGC, dentogingival complex; GT, gingival thickness; GW, gingival width; KT, keratinized tissue; TRAN, periodontal probe transparency.

using tridimensional images was the inclusion of the cone-beam computed tomography (CBCT) especially the soft tissue CBCT (ST-CBCT) for clear visualization and measurement of periodontal structures and dentogingival attachment apparatus.[34]

Further cluster investigations were made in 2009. De Rouck et al.[15] confirmed the existence of three gingival biotypes (A1, A2, and B) when a large sample of periodontally healthy volunteers was studied using the TRAN method. According to the authors, the cluster A1 characteristics seemed to correspond with the "thin-scalloped" biotype, whereas the cluster B characteristics, with the "thick-flat" biotype. However, the cluster A2 could not be classified as either A1 or B. Around this time, Eghbali et al.[35] used the cluster analysis performed earlier by De Rouck et al.[15] to evaluate the precision of direct visual inspection (clinical slides) as a method to identify the gingival biotype. Finally, a key development in the periodontal phenotype field was the thick biotype sub-classification. Hence, "thin-scalloped", "thick-scalloped" and "thick-flat" biotypes were proposed considering that "thick-scalloped" biotype has characteristics in common with both other more extreme biotypes.[15,35] Further studies highlighted the reliability of the TRAN and CBCT methods for evaluating gingival biotype,[36] and clinical thickness of both buccal gingiva and bone.[12] Table 3 presents the main studies of the Third Era of periodontal phenotype (2000-2010).

Accumulating evidence during the previous periods shows that three periodontal biotypes ("thin-scalloped", "thick-scalloped", and "thick-flat") are recognized based in distinct characteristics associated with GT, gingival morphotype, bone morphotype and tooth dimensions, respectively.[8] Further evidence reported that a thin periodontal biotype was associated with a thinner buccal bone plate thickness (BBPT) different to thick/average periodontal biotype.[37] In addition, Zweers et al.[8] is credited for the highly recognized systematic review where "thin-scalloped," "thick-scalloped," and "thick-flat" periodontal biotypes were reported. In 2015, Fischer et al.[38] provided evidence of four groups defined as "very thin," "thin," "thick," and "very thick" gingival biotypes. These studies compose the body of evidence supporting the Forth Era of periodontal phenotype (2011-2018).

Investigations have also used cluster analysis to include GT, BBPT, bone crest to the gingival margin, bone crest to the CEJ, and crown length measurements using CBCT technology. Hence, "thin," "average," "mixed," and "thick" periodontal biotypes were identified.[39] Meanwhile, some investigators performed novel classifications relying on to the introduction of especial periodontal probes for the TRAN method. In line with this, Fischer et al.[40] introduced a new classification using a doble-ended periodontal probe as an assessment tool for the TRAN method execution. Accordingly, "thick", "moderate", and "thin" gingival biotypes were reported considering the visibility of a periodontal probe with two unequal thick endings through the sulcus.[40] Similarly, Kloukos et al.[41] compared four methods for GT evaluation and identified "thin," "medium," "thick," and "very thick" gingival phenotypes after the use of a special periodontal probe with a colored tip (white, green, and blue).

Breakthrough studies published in the Fourth Era of periodontal phenotype (2011-2018) include the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions where information about periodontal manifestations of systemic diseases and developmental and acquired conditions were focused in the workgroup 3 led by professor Søren Jepsen.[9] Considering the development of gingival recession associated with the gingival phenotype, the workgroup 3 highlighted the differences between biotype and phenotype. In simple words, biotype is genetically predetermined, cannot be modified and does not incorporate environmental factors and clinical intervention that can alter the periodontal tissue profile. On the other hand, phenotype can be defined as the appearance of an organ based on a multifactorial combination of genetic traits and environmental factors; for that, its expression includes the biotype.[9] In addition, phenotype refers to the observable properties of an organism that are produced by the interaction of the genotype and the environment.[42] Hence, periodontal phenotype can be modified by clinical interventions and environmental factors, such as orthodontics, overhanging restorations, or autogenous gingival grafting procedures.[9]

Accordingly, the recent World Workshop recommended the adoption of the term phenotype to describe the combination of the gingival phenotype, constituted by the GT and the KTW, and the bone morphotype, that is, BBPT. In addition, the World Workshop also recommended to use a periodontal probe in a standardized and reproducible way to measure the GT observing the periodontal probe shining through gingival tissue after being inserted into the sulcus.[9] However, it is important to mention that another review of the recent World Workshop reported by Cortellini and Bessada,[10] focused on the periodontal biotype. In this regard, these investigators considered the classification proposed by Zweers et al.[8] where the periodontal biotype was categorized in "thin-scalloped", "thick-scalloped", and "thick-flat". On the other hand, a recent review article published by Avila-Ortiz et al.[43] analyzed the components of the periimplant phenotype (soft tissue and bone) as an analogous term of periodontal phenotype. Based in the all aforementioned classifications, characteristics, and definitions, it is worthwhile to note that periodontal phenotype is the recommended term used for future investigations. Table 4 depicts the ultimately main studies of the Fourth Era of periodontal phenotype (2011-2018).

3 | PERIODONTAL PHENOTYPE EVALUATION

Periodontal phenotype can be evaluated considering the gingival phenotype (GT and KTW) and the bone morphotype (BBPT) components. In the following section, the identified methods for periodontal phenotype evaluation were divided on clinical autopsy, clinical or radiographic assessment and direct vision/measurement assessments. Table 5 summarizes important information about advantages and disadvantages of the methods as well as the variants of each described technique.

3.1 | Clinical autopsy

Autopsy evaluation has been performed in dry human skulls,[17,21,29] extracted teeth,[18] fresh cadaver heads,[12] and histologic images.[44] Earliest reports of maxillary and mandibular dry human skulls, and

TABLE 3 Characteristics of classification possibilities in the Third Era of periodontal phenotype: 2000–2010

Autor (year)	Study object/subject	Method of evaluation	Classifications, characteristics, and considerations about periodontal phenotype
Müller et al. (2000)[14]	All teeth	Clinical, ultrasonic device, study casts, caliper	Periodontal phenotype. “Cluster A1” (Thin): Thin GT, narrow width of KT, slender teeth. “Cluster A2” (Thin): Thin GT, wide KT, slender teeth. “Cluster B" (Thick): Thick GT, wide KT, quadratic teeth.
Pontoriero and Carnevale (2001)[32]	One or more teeth hampering restorative measurements	Clinical	Tissue biotype. “Thin, normal and thick”. After surgical crown lengthening the coronal regrowth of the soft tissues margin was significantly more pronounced in patients with thick tissue biotype than patients with thin tissue biotype.
Aimetti et al. (2008)[33]	Maxillary anterior region	Clinical, transgingival endodontic reamer	Gingival phenotypes. “Thin”: GT ≤1 mm. “Flat thick”: GT > 1 mm.
Januário et al. (2008)[34]	Maxillary right central incisor	ST-CBCT scan	Periodontal biotype. “Thin, normal, and thick”. Considerations about the dimensions and the relationship of the periodontium structures and the dentogingival attachment apparatus.
De Rouck et al. (2009)[15]	Maxillary central incisors	Clinical, TRAN	Gingival biotype. “Cluster A1”: Thin GT, narrow zone of KT, slender teeth, highly scalloped gingival margin. “Cluster A2”: Thick GT, narrow zone of KT, slender teeth, highly scalloped gingival margin. “Cluster B": Thick GT, broad zone of KT, quadratic teeth, flat and slightly scalloped gingival margin.
Eghbali et al. (2009)[35]	Maxillary anterior region	Clinical slides	Gingival biotype. “Thin-scalloped”: Thin GT, narrow zone of KT, slender teeth, highly scalloped gingival margin. “Thick-scalloped”: Thick GT, narrow zone of KT, slender teeth, high gingival scallop. “Thick-flat”: Thick GT, broad zone of KT, quadratic teeth, flat gingival margin.
Kan et al. (2010)[36]	Maxillary anterior region	Clinical, TRAN, tension-free caliper	Gingival biotype. “Thin”: Delicate, friable, and almost translucent. Visibility of the periodontal probe through the gingival tissue. GT ≤1.0 mm. “Thick”: Dense and fibrotic. Periodontal probe not visible. GT: > 1.0 mm.
Fu et al. (2010)[12]	Fresh cadaver heads/Maxillary anterior region	Clinical autopsy, TRAN, CBCT-scan, tension-free caliper	Tissue biotype. “Thin”: Outline of the periodontal probe visualized through the gingival margin. “Thick”: Outline of the periodontal probe not visualized.

Abbreviations: GT, gingival thickness; KT, keratinized tissue; ST-CBCT, soft tissue cone-beam computed tomography; TRAN, periodontal probe transparency.

extracted teeth were the historical beginnings for the future knowledge about specific periodontal phenotype characteristics.

3.2 | Clinical or radiographic assessment

Considering the identified information, clinical or radiographic GT assessment can be divided in invasive and noninvasive methods. On the other hand, KTW can be assessed with static and functional methods, whereas BBPT can be measured considering bidimensional and tridimensional techniques.

3.2.1 | Invasive methods for GT evaluation

Transgingival probing

This invasive method comes from the bone sounding technique used for plotting the morphological outline of the bone (bone mapping) as

TABLE 4 Characteristics of classification in the Fourth Era of periodontal phenotype: 2011–2018

Autor (year)	Study object/subject	Method of evaluation	Classifications, characteristics, and considerations about periodontal phenotype
Cook et al. (2011)[37]	Maxillary anterior region	Clinical, TRAN, ST-CBCT scan, study casts	Periodontal biotype: "Thin": Flat or scalloped gingival architecture, probe seen through the gingiva. "Thick/average": Flat or scalloped gingival architecture, probe not seen through the gingiva.
Zweers et al. (2014)[8]			Periodontal biotype: "Thin scalloped": Clear thin delicate gingiva, narrow zone of KT, slender triangular shaped crowns, subtle cervical convexity, interproximal contacts close to the incisal edge, and a relatively thin alveolar bone. "Thick scalloped": Clear thick fibrotic gingiva, high gingival scallop, narrow zone of KT, and slender teeth. "Thick flat": Clear thick fibrotic gingiva, broad zone of KT, more square shaped tooth crowns, pronounced cervical convexity, large interproximal contact located more apically, and a comparatively thick alveolar bone.
Fischer et al. (2015)[38]	Maxillary anterior region	Clinical, TRAN, study casts, digital caliper	Gingival biotype. "Very thin": The lowest GT. "Thin": Probe seen through the gingiva. "Thick": Probe not seen through the gingiva. "Very thick": The highest GT.
Nikiforidou et al. (2016)[39]	Maxillary anterior region	Clinical, CBCT-scan	Periodontal biotype. "Thin, average, mixed, and thick". Numerical data about GT, CL, buccal bone plate thickness, bone crest to the CEJ, bone crest to the GM.
Fischer et al. (2018)[40]	Maxillary left central incisors	Clinical, TRAN, digital caliper	Gingival biotype: Double-ended periodontal probe. "Thick": The thick probe ending is not detectable through the sulcus. "Moderate": The thick probe ending is visible through the sulcus but the other thin ending is not visible. "Thin": The thin probe is noticeable.
Kloukos et al. (2018)[41]	Mandibular central incisors	Clinical, TRAN, transgingival acupuncture needle, ultrasonic device	Gingival phenotype. Visibility of a periodontal probe with a colored tip (white, green, and blue) through the gingiva. "Thin": White tip visible. "Medium": White tip is not visible, but the green tip is. "Thick": Green tip is not visible, but the blue tip is. "Very thick": Not even the blue tip is visible.
Cortellini and Bissada (2018)[10]			Periodontal biotype. "Thin-scalloped", "thick-scalloped", and "Thick-flat". The same characteristics proposed by Zweers et al.[8]
Jepsen et al. (2018)[9]			Periodontal phenotype. "Gingival phenotype": Gingival thickness, keratinized tissue width. "Bone morphotype": Buccal bone plate thickness. "Thin": GT ≤1 mm. Probe seen through the gingiva. "Thick": GT > 1 mm. Probe not seen.

Abbreviations: CEJ, cementoenamel junction; CL, crown length; GM, gingival margin; GT, gingiva thickness. KT, keratinized tissue; ST-CBCT, soft tissue cone-beam computed tomography; TRAN, periodontal probe transparency.

an estimator of alveolar bone level.[45,46] Greenberg et al.[47] modified the sounding technique term for transgingival probing, and this term was used later for GT evaluation. Originally, the technique consists on the use of local anesthesia and a periodontal probe positioned perpendicularly to pierce the soft tissue surface until reaching resistance of the bone. In the beginning, stainless-steel wire (0.4 mm diameter),[24] and a disposable sterile syringe needle (0.40 mm/27G)[6] were used. Subsequently, endodontic reamer,[33] spreader,[48] files,[49] or disposable acupuncture needles[41] were also used for this propose. In addition, a rubber stopper (endodontic deep marker) in contact with the tissue is necessary to assess the GT measurement. The rubber stopper in contact with the tissue can be fixed using cyanoacrylate to impede slipping.[50] However, due to additional implements, some authors[51] recommend to use flowable composites instead of a rubber stopper (the latest two studies above mentioned were done for measurement palatal mucosa thickness). Finally, the distance between the rubber stopper or composite and the tip of the instruments can be measured round off the nearest 0.5 mm using light

TABLE 5 Summary of methods to evaluate periodontal phenotype

Clinical autopsy/clinical or radiographic assessment/direct vision	Gingival phenotype/bone morphotype/complements	Methods of evaluation	Variants/considerations	Advantages	Disadvantages
Clinical autopsy		Autopsy evalutation	- Dry human skulls[17,21,29] - Extracted teeth[18] - Fresh cadaver heads[12] - Histologic images[44]	- Broad overview - Proper handling	- Special tool/apparatus necessary - Special study enviroments - Time necessary
Clinical or radiographic assessment a	GT invasive methods	Transgingival probing	- Periodontal probe[47] - Stainless-steel wire[24] - Syringe needle[6] - Endodontic reamer,[33] spreader,[48] file[49] - Acupuncture needle[41]	- Time effective - Suitable in clinical settings - Not special tool necessary - Several variants	- Local anesthesia necessary - Unpleasant for patient - Possible volume changes through anesthesia - Precision, postion, and angulation variable - Possible slipping of the rubber stopper - Values need to be rounded off - Possible periosteum/lamina dura perforation in excessive puncture strength
		Transformer probe	- Not variants, original method[53,54]		- Local anesthesia necessary. Painful - Special tool necessary - Posterior region less accessible for meassurements - Unavailability, limited practicability in clinical setting - Litle scientific evidence
	GT Non-invasive methods	Ultrasonic device	- Ultrasonic echo-ranging principle[55] - Ultrasonic pulse-echo principle[7,14,41,56] - Ultrasonic biometer[57,58]	- Painless - Atraumatic and straightforward	- Special tool necessary - Posterior region less accessible for meassurements - Directionality of the transducer variable - Unavailability and high costs - Limited practicability in clinical setting

TABLE 5 (Continued)

	Calipers	- Tension-free manual caliper: - Boley gauge,[12,27] - Iwanson gauge[36] - Digital caliper[38,40,63]	- Direct measurement expresed in numbers - Objective - Customized, technological, and straightforward (digital) - Used in pretreatment evaluation (digital)	- Spring removal is necessary (manual) - The values need to be rounded off (digital to 0.01 mm) - Used only in surgery intervention (manual) - Some regions less accessible for measurements (digital)
	Periodontal probe transparency (TRAN method)	- Standard periodontal probe[9,12,15,36-38] - Double-ended periodontal probe[40] - Colored periodontal probe tip[41]	- Painless, not discomfort - Time effective - Suitable in clinical setting - Not special tool necessary - Atraumatic, straightforward, and economical -Reliable and reproducible	- GT not expressed in numbers - Only two categories possible (standard periodontal probe)
	Parallel profile radiograph (PPRx)	- Periapical film plus gutta-percha point,[66,67] lead plate,[67,68] metal strip[69] - Occlusal film plus plastic lip retractor[69]	- Straightforward - X-ray apparatus widely available - Buccal gingiva and buccal bone measurement (limited)	- Slight discomfort (gutta-percha point in sulcus) - Only in front region possible (maxillary or mandibular) - Absolute parallelism of film and tooth necessary - Limited practicability in clinical setting - Exposure to radiation
	Cone-beam computed tomography (CBCT)	- Soft tissue CBCT: Cotton rolls,[39] plastic lip retractor,[34] plastic lip retractor plus wooden spatula,[71] acrylic plates with radiopaque guide,[49] puffed check technique[72]	- Not painful - Tridimensional overview over anatomical structures - Additional therapeutic information - Buccal gingiva and buccal bone measurement (complete)	- Exposure to radiation - Dental indication necessary - Cost
KTW static methods	Visual assessment	- Clinical appearance (CA)[6,7,15,38,40,73] - Histochemical staining (HS)[53,74-77]	- Not special tool necessary (CA) - Time effective (CA)	- Unreliable perception (CA) - Posterior region less accessible - Values need to be rounded off - Allergies and strains possible (HS) - Bad taste (HS)

(Continues)

TABLE 5 (Continued)

					- Iodine solution necessary (HS)
	KTW functional methods	Pushing technique	- Not variants, original technique[6,38,40,75-79]	- Not special tool necessary - Painless - Atraumatic	- Slight discomfort (if high pressure is exerted)
	Bidimensional BBPT	Parallel profile radiograph (PPRx)	- Same as above	- Same as above	- Same as above
	Tridimensional BBPT	Cone-beam computed tomography (CBCT)	- Same as above	- Same as above	- Same as above
Direct vision/ measurement	Complements	Visual assessment	- Clinical appearance	- Complementary tools	- Not standardized
		Oral radiographs[19]	- Alveolar bone		- Clinical/radiological experience necessary
		Oral photographs[6,20,25,35]	- Anterior/posterior region		- Subjective - Not recomendable as a diagnostic predictor
		Study casts[6,7,14,37,38,62,80]	- CW/CL,[6,7,14,37] DPC[62,80]	- Complementary tools	- Time necessary
		Alginate impressions[81]	- Papillaes[81]		

Abbreviations: BBPT, buccal bone plate thicness; CW/CL, crown width/crown length ratio; DPC, dento-papillary complex; GT, gingival thickness. KTW, keratinized tissue width.

microscope,[6] calipers,[41] or endodontic rulers.[48] For reproducible measurements of specific sites, as for example palatal mucosa thickness, a study cast with an acrylic transparent splint was recommended. Measurement holes in the splint are used as a guiding path for the instrument (periodontal probe or needle) once the splint is placed back on the patient´s mouth.[52,53]

Transformer probe

This method was proposed for measuring GT based in a differential transformer coupled to an oscillator and digital voltmeter. The probe assembly showed an accuracy of 0.01 mm, whereas the average range of difference in replicate measurements was below 0.15 mm.[53,54] The information about this method is scarce.

3.2.2 | Noninvasive methods for GT evaluation

Ultrasonic device

This method utilizes ultrasound wave distribution, dispersion, and reflection on an interface. Initially, the ultrasonic echo-ranging instrumentation was used to measure the resting thickness of masticatory mucosa and the change in thickness as a result of compressive mechanical stress.[55] Later, more sophisticated ultrasonic devices (3 mm diameter of transducer probe and weight of 19 g) based on the pulse-echo principle were used in important investigations about gingival phenotype.[7,14,41,56] Moreover, ultrasonic biometer was also reported.[57,58] In some reports ultrasonic devices are considered as the most noninvasive methods.[36]

Calipers

This device has been used with acrylic template as a guide to measure changes in pre and postoperative free gingival grafts,[59] as well as to measure mucogingival flap reflection at the time of guided tissue regeneration surgery.[27] In addition, specific distances in study casts,[14] and soft and hard tissue dimensions[12,36] can also be measured using this instrument. It is recommended to modify the caliper by cutting the spring in order to eliminate the tension of the arms avoiding excessive pressure on the evaluated tissues.[60] A special manual caliper designed with minimal tension is also available. In the periodontal field, Boley gauge caliper[12,27] and Iwanson caliper[36] are the most used calipers. Besides that, the Iwanson caliper can be modified with two extended arms (tips of two periodontal probes) fused by the head gauge. One arm is pushed underneath the gingival sulcus and another arm is over the tissues.[61,62] However, the scientific evidence is scarce about this modified caliper. Recently, a customized digital caliper has been introduced for GT measurement with a minimal spring force (4 N/mm^2).[38,40,63]

Reportedly, the most common cutoff dimension to separate thick and thin GT is 1.0 mm,[9,27,33,36] However, a systematic review considered this numerical assignment as an arbitrary categoryzation.[64] Caliper instruments are considered the most objective method but its clinical use may provide some challenges.[36]

Periodontal probe transparency

Earlier reports used an amalgam matrix band to identify the translucency of gingival marginal thickness prior to restorative procedures to avoid the gray shade of the metal-ceramic crowns through the tissues.[65] Later, GT was categorized as thin if the outline of the periodontal probe was visible through the gingival margin and thick, if it was not visible.[12,15,36-38] Recently, double-ended periodontal probe[40] and periodontal probe with a colored tip (white, green, and blue)[41] were included as special instruments to analyze the GT using the TRAN method. Currently, the World Workshop recommended to assess the periodontal phenotype using the TRAN method. The probe will be visible in thin periodontal phenotypes (≤1 mm) and will not be visible in thick periodontal phenotypes (>1 mm).[9] However, based in three gingival phenotypes identified,[8,10,15,35] the TRAN method indicates thin GT for "thin-scalloped" phenotypes, and thick GT for "thick-scalloped" and "thick-flat" gingival phenotypes, respectively. In addition, other characteristics must be considered to differentiate the three periodontal phenotypes. According to the literature, the TRAN method is highly reliable[36] and reproducible.[15] Also, it is one of the most frequently used methods to analyze periodontal phenotypes.[9,12,15,36-38,40,41]

Parallel profile radiographs

This method was proposed for measuring the dentogingival unit on the buccal surfaces of anterior teeth using the long cone parallel technique.[66] A gutta-percha point cut to the known sulcus depth was inserted to the base of the sulcus; the apical end of the point marks the bottom of the sulcus, the coronal end depicts the gingival margin, and buccally it defined the inner surface of the free gingiva. Two radiographs were made, one in a frontal projection, and the second (parallel profile radiographs [PPRx]) in a lateral position using a periapical film holding system.[53,66] Also a self-sticking lead plate or metal strip ($5.0 \times 1.0 \times 0.1$ mm^3)[67-69] well aligned to the long axis of the tooth and with the edge of the gingival margin is positioned (reference point) delimiting the gingival profile up to the gingival margin. Occlusal films and plastic lip retractors are variants of this radiographic morphometric technique or tangential radiography.[69] According to the literature, the thickness of some structures as for example free gingiva, gingiva at the supracrestal attachment, attached gingiva, and BBTP can be measured.[67,68]

Cone-beam computed tomography

CBCT was introduced as a volumetric computed tomography, uses the cone-beam technique instead of traditional fan-beam technique and is specially devoted to maxillofacial imaging.[70] The ST-CBCT was proposed as a variant to retract the soft tissues (lip, cheeks, and tongue) away from the gingiva in both buccal and palatal aspects. Thus, a dark air-filled space is created which makes an important distinction between soft and hard tissues.[34] Dentogingival unit dimensions,[34] palatal mucosa thickness,[71] crowns length,[39] maxillary and mandibular BBPT,[49] has been measured using ST-CBCT. For retraction of the soft tissues, plastic lip retractor,[34] plastic lip retractor plus wooden spatula across the mouth,[71] cotton rolls,39 acrylic plates with radiopaque guides,[49] or the puffed cheek technique[72] have been recommended.

3.2.3 | Static methods for KTW evaluation

Visual assessment

Visual assessment of the KTW can be performed through clinical appearance evaluation and histochemical staining. Clinical appearance is based on the mucogingival junction identification that represents the separation line between the keratinized tissue and the alveolar mucosa. The evaluation represents the distance measured mid-buccally, to the nearest mm, from the free gingival margin to the mucogingival junction.[6,7,15,38,40,73] Generally, caliper instruments[7] or periodontal probes[15,38,40] have been used for the measurement. On the other hand, KTW can be assessed visually after staining the mucogingival complex with Schiller[53] or Lugol iodine solution (iodine test).[74-77] This technique is based on the difference in the glycogen content between the alveolar mucosa (high glycogen content) and the keratinized tissue (low glycogen content). Thus, the iodine test clearly demarcates the mucogingival line. Later, a periodontal probe with a rubber stopper can be used for measurements.[74]

3.2.4 | Functional methods for KTW evaluation

Pushing technique

The mucogingival line can be estimated as a borderline between the movable and immovable tissue. The mobility of tissue is determined using a periodontal probe that is positioned horizontally from the vestibule toward the gingival margin using light pressure.[75-78] This method is also named as wrinkle technique.[6,38,40,79]

3.2.5 | Bidimensional BBPT

Parallel profile radiographs have been used as an alternative method for BBPT in a bidimensional plane.[66-69] However, the information obtained is limited to the anterior region.[53]

3.2.6 | Tridimensional BBPT

ST-CBCT is a more reliable method for BBPT.[12,37,39] However, it is not recommended for the specific bone morphotype evaluation but it can be proposed as a tool for additional therapeutic information.[9]

3.3 | Direct vision/measurement

Earlier studies reported important information about gingival characteristics considering only visual assessments. Classically, dense and fibrotic gingival appearance has been considered as thick; whereas friable, delicate, and translucent gingiva has been considered as thin.[5,23,36] Oral radiographs[19] and oral photographs,[6,20,25,35] were also used. Moreover, several investigations used study casts to analyze the relationship between tooth dimensions and periodontal characteristics (dento-papillary complex).[6,7,14,37,38,62] Finally, virtual models[80] and alginate impressions[81] are considered as complements for gingival phenotype evaluation.

The present study tried to analyze a historical perspective of periodontal phenotype. Despite the fact that periodontology is not based on anatomical features as it has been in the past, it is recognized that periodontal phenotype has an importance in gingival recession and correct position of soft tissue around implants, especially concerning esthetics. In clinical periodontology, the anatomical features do not display a role in pathogenesis of periodontal breakdown. However, this might not be the same in implantology. Therefore, knowledge about these anatomical features is an important part of integral clinical periodontology. Also, it should be highlighted that the surrounding bone has an importance on periodontal phenotype.

4 | CONCLUSIONS

The classification systems emphasize "thin-scalloped," "thick-scalloped," and "thick-flat" periodontal biotypes. These three periodontal biotypes have been considered in the World Workshop but the term periodontal phenotype is recommended. Periodontal phenotype is the combination of the gingival phenotype (GT and KTW) and bone morphotype (BBPT).

The periodontal phenotype can be evaluated through clinical or radiographic assessment divided into in/noninvasive (for GT), static/functional (for KTW), and bi/tridimensional (for BBPT) methods. In addition, clinical autopsy and direct vision/measurements have been used in earliest studies, today considered as complementary tools for periodontal phenotype evaluation.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

ORCID

Violeta Malpartida-Carrillo https://orcid.org/0000-0003-1678-6282
Pedro Luis Tinedo-Lopez https://orcid.org/0000-0002-2102-4437
Maria Eugenia Guerrero https://orcid.org/0000-0001-5425-870X
Silvia P. Amaya-Pajares https://orcid.org/0000-0001-6894-7186
Mutlu Özcan https://orcid.org/0000-0002-9623-6098
Cassiano Kuchenbecker Rösing https://orcid.org/0000-0002-8499-5759

REFERENCES

1. Abraham S, Deepak KT, Ambili R, Preeja C, Archana V. Gingival biotype and its clinical significance—a review. *Saudi J Den Res*. 2014;5:3-7.
2. Cook R, Lim K. Update on perio-prosthodontics. *Dent Clin N Am*. 2019;63:157-174.
3. Kim DM, Bassir SH, Nguyen TT. Effect of gingival phenotype on the maintenance of periodontal health: an American Academy of periodontology best evidence review. *J Periodontol*. 2020;91:311-338.
4. Shah R, Sowmya NK, Thomas R, Mehta DS. Periodontal biotype: basics and clinical considerations. *J Inter Dent*. 2016;6:44-49.
5. Seibert J, Lindhe J. Esthetics and periodontal therapy. In: Lindhe J, ed. *Textbook of Clinical Periodontology*. 2nd ed. Copenhagen, Denmark: Munksgaard; 1989:477-514.
6. Olsson M, Lindhe J, Marinello CP. On the relationship between crown form and clinical features of the gingiva in adolescents. *J Clin Periodontol*. 1993;20:570-577.
7. Müller HP, Eger T. Gingival phenotypes in young male adults. *J Clin Periodontol*. 1997;24:65-71.
8. Zweers J, Thomas RZ, Slot DE, Weisgold AS, van der Weijden FGA. Characteristics of periodontal biotype, its dimensions, associations and prevalence: a systematic review. *J Clin Periodontol*. 2014;41:958-971.
9. Jepsen S, Caton JG, Albandar JM, et al. 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*. 2018;89:237-248.
10. Cortellini P, Bissada NF. Mucogingival conditions in the natural dentition: narrative review, case definitions, and diagnostic considerations. *J Periodontol*. 2018;89:204-213.
11. Kennedy JE. Effect of inflammation on collateral circulation of the gingiva. *J Periodontal Res*. 1974;9:147-152.
12. Fu JH, Yeh CY, Chan HL, Tatarakis N, Leong DJM, Wang HL. Tissue biotype and its relation to the underlying bone morphology. *J Periodontol*. 2010;81:569-574.
13. Thoma DS, Mühlemann S, Jung RE. Critical soft-tissue dimensions with dental implants and treatment concepts. *Periodontol 2000*. 2014;66:106-118.
14. Müller HP, Heinecke A, Schaller N, Eger T. Masticatory mucosa in subjects with different periodontal phenotypes. *J Clin Periodontol*. 2000;27:621-626.
15. De Rouck T, Eghbali R, Collys K, et al. 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*. 2009;36:428-433.
16. Ciok E, Górski B, Fester A, Zadurska M. Methods of gingival biotype assessment. *J Stoma*. 2014;67:460-469.
17. Hirschfeld I. A study of skulls in the American museum of natural history in relation to periodontal disease. *J Dent Res*. 1923;5:241-265.
18. Wheeler RC. *Textbook of Dental Anatomy and Physiology*. Philadelphia & London: W. B. Saunders Co.; 1940.
19. Ritchey B, Orban B. The crests of the interdental alveolar septa. *J Periodontol*. 1953;24:75-87.
20. Morris ML. The position of the margin of the gingiva. *Oral Surg Oral Med Oral Pathol*. 1958;11:969-984.
21. TW O´C, Biggs N. Interproximal craters. *J Periodontol*. 1964;35:326-330.
22. Ochsenbein C, Ross S. A reevaluation of osseous surgery. *Dent Clin N Am*. 1969;13:87-102.
23. Weisgold AS. Contours of the full crown restoration. *Alpha Omegan*. 1977;70:77-89.
24. Claffey N, Shanley D. Relationship of gingival thickness and bleeding to loss of probing attachment in shallow sites following nonsurgical periodontal therapy. *J Clin Periodontol*. 1986;13:654-657.
25. Olsson M, Lindhe J. Periodontal characteristics in individuals with varying form of the upper central incisors. *J Clin Periodontol*. 1991;18:78-82.
26. Kois JC. Altering gingival levels: the restorative connection. Part 1: biologic variables. *J Esthet Restor Dent*. 1994;6:3-7.
27. Anderegg CR, Metzler DG, Nicoll BK. Gingiva thickness in guided tissue regeneration and associated recession at facial furcation defects. *J Periodontol*. 1995;66:397-402.
28. Harris RJ. A comparative study of root coverage obtained with guided tissue regeneration utilizing a bioabsorbable membrane versus the connective tissue with partial-thickness double pedicle graft. *J Periodontol*. 1997;68:779-790.

29. Becker W, Ochsenbein C, Tibbetts L, Becker BE. Alveolar bone anatomic profiles as measured from dry skulls. Clinical ramifications. *J Clin Periodontol*. 1997;24:727-731.
30. Sanavi F, Weisgold AS, Rose LF. Biologic width and its relation to periodontal biotypes. *J Esthet Restor Dent*. 1998;10:157-163.
31. Kan JY, Rungcharassaeng K, Umezu K, Kois JC. Dimensions of peri-implant mucosa: an evaluation of maxillary anterior single implants in humans. *J Periodontol*. 2003;74:557-562.
32. Pontoriero R, Carnevale G. Surgical crown lengthening: a 12-month clinical wound healing study. *J Periodontol*. 2001;72:841-848.
33. Aimetti M, Massei G, Morra M, Cardesi E, Romano F. Correlation between gingival phenotype and Schneiderian membrane thickness. *Int J Oral Maxillofac Implants*. 2008;23:1128-1132.
34. Januário AL, Barriviera M, Duarte WR. Soft tissue cone-beam computed tomography: a novel method for the measurement of gingival tissue and the dimensions of the dentogingival unit. *J Esthet Restor Dent*. 2008;20:366-373.
35. Eghbali A, De Rouck T, De Bruyn H, Cosyn J. The gingival biotype assessed by experienced and inexperienced clinicians. *J Clin Periodontol*. 2009;36:958-963.
36. Kan JY, Marimoto T, Rungcharassaeng K, Roe P, Smith DH. Gingival biotype assessment in the esthetic zone: visual versus direct measurement. *Int J Periodontics Restorative Dent*. 2010;30:237-243.
37. Cook DR, Mealey BL, Verrett RG, et al. Relationship between clinical periodontal biotype and labial plate thickness: an in vivo study. *Int J Periodontics Restorative Dent*. 2011;31:345-354.
38. Fischer KR, Richter T, Kebschull M, Petersen N, Fickl S. On the relationship between gingival biotypes and gingival thickness in young Caucasians. *Clin Oral Implants Res*. 2015;26:865-869.
39. Nikiforidou M, Tsalikis L, Angelopoulos C, Menexes G, Vouros I, Konstantinides A. Classification of periodontal biotypes with the use of CBCT. A cross-sectional study. *Clin Oral Investig*. 2016;20:2061-2071.
40. Fischer KR, Künzlberger A, Donos N, Fickl S, Friedmann A. Gingival biotype revisited-novel classification and assessment tool. *Clin Oral Investig*. 2018;22:443-448.
41. Kloukos D, Koukos G, Doulis I, Sculean A, Stavropoulos A, Katsaros C. Gingival thickness assessment at the mandibular incisors with four methods: a cross-sectional study. *J Periodontol*. 2018;89:1300-1309.
42. Merriam-webster.com [Internet]. Massachusetts: Merriam-webster Dictionary; [cited 2020 Aug 09]. https://www.merriamwebster.com/dictionary/phenotype#medicalDictionary 2020.
43. Avila-Ortiz G, Gonzales-Martin O, Couso-Queiruga E, Wang HL. The peri-implant phenotype. *J Periodontol*. 2020;91:283-288.
44. Gonçalves Motta SH, Ferreira Camacho MP, Quintela DC, Santana RB. Relationship between clinical and histologic periodontal biotypes in humans. *Int J Periodontics Restorative Dent*. 2017;37:737-741.
45. Strahan JD. Relation of mucogingival junction to alveolar bone margin. *Acad Rev Calif Acad Periodontol*. 1965;13:23-28.
46. Easley JR. Methods of determining alveolar osseous form. *J Periodontol*. 1967;38:112-118.
47. Greenberg J, Laster L, Listgarten MA. Transgingival probing as a potential estimator of alveolar bone level. *J Periodontol.* 1976;47:514-517.
48. Kolte R, Kolte A, Mahajan A. Assessment of gingival thickness with regards to age, gender and arch location. *J Indian Soc Periodontol*. 2014;18:478-481.
49. Shao Y, Yin L, Gu J, Wang D, Lu W, Sun Y. Assessment of periodontal biotype in a young Chinese population using different measurement methods. *Sci Rep*. 2018;8:11212.
50. Tavelli L, Ravidà A, Saleh MHA, et al. Pain perception following epithelialized gingival graft harvesting: a randomized clinical trial. *Clin Oral Investig*. 2019;23:459-468.
51. Maino GNE, Valles C, Santos A, Pascual A, Esquinas C, Nart J. Influence of suturing technique on wound healing and patient morbidity after connective tissue harvesting. A randomized clinical trial. *J Clin Periodontol*. 2018;45:977-985.
52. Gupta N, Hungund S, Astekar MS, Dodani K. Evaluation of palatal mucosal thickness and its association with age and gender. *Biotech Histochem*. 2014;89:481-487.
53. Ronay V, Sahrmann P, Bindl A, Attin T, Schmidlin PR. Current status and perspectives of mucogingival soft tissue measurement methods. *J Esthet Restor Dent*. 2011;23:146-156.
54. Goaslind GD, Robertson PB, Mahan CJ, Morrison WW, Olson JV. Thickness of facial gingiva. *J Periodontol*. 1977;48:768-771.
55. Kydd WL, Daly CH, Wheeler JB. The thickness measurement of masticatory mucosa in vivo. *Int Dent*. 1971;21:430-441.
56. Eger T, Müller HP, Heinecke A. Ultrasonic determination of gingival thickness. Subject variation and influence of tooth type and clinical features. *J Clin Periodontol*. 1996;23:839-845.
57. Bednarz W, Zielińska A. Ultrasonic biometer and its usage in an assessment of periodontal soft tissue thickness and comparison of its measurement accuracy with a bone sounding method. *Dent Med Probl*. 2011;48:481-489.
58. Gánti B, Bednarz W, Kőműves K, Vág J. Reproducibility of the PIROP ultrasonic biometer for gingival thickness measurements. *J Esthet Restor Dent*. 2019;31:263-267.
59. Fagan F, Freeman E. Clinical comparison of the free gingival graft and partial thickness apically positioned flap. *J Periodontol*. 1974;45:3-8.
60. Baldi C, Pini-Prato G, Pagliario U, et al. Coronally advanced flap procedure for root coverage. Is flap thickness a relevant predictor to achieve root coverage? A 19-case series. *J Periodontol*. 1999;70:1077-1084.
61. Memon S, Patel JR, Sethuraman R, Patel R, Arora H. A comparative evaluation of the reliability of three methods of assessing gingival biotype in dentate subjects in different age groups: an in vivo study. *J Indian Prosthodont Soc*. 2015;15:313-317.
62. Nagate RR, Tikare S, Chaturvedi S, AlQahtani N, Kader MA, Gokhale ST. A novel perspective for predicting gingival biotype via dentopapillary measurements on study models in the Saudi population: cross-sectional study. *Niger J Clin Pract*. 2019;22:56-62.
63. Liu F, Pelekos G, Jin LJ. The gingival biotype in a cohort of Chinese subjects with and without history of periodontal disease. *J Periodontal Res*. 2017;52:1004-1010.
64. Hwang D, Wang HL. Flap thickness as a predictor of root coverage: a systematic review. *J Periodontol*. 2006;77:1625-1634.
65. Kaiser DA, Hummert TW. Assessment of gingival margin thickness before margin placement. *J Prosthet Dent*. 1994;71:325-326.
66. Alpiste-Illueca F. Dimensions of the dentogingival unit in maxillary anterior teeth: a new exploration technique (parallel profile radiograph). *Int J Periodontics Restorative Dent*. 2004;24:386-396.
67. Galgali SR, Gontiya G. Evaluation of an innovative radiographic technique-parallel profile radiography-to determine the dimensions of dentogingival unit. *Indian J Dent Res*. 2011;22:237-241.
68. Stein JM, Lintel-Höping N, Hammächer C, Kasaj A, Tamm M, Hanisch O. The gingival biotype: measurement of soft and hard tissue dimensions-a radiographic morphometric study. *J Clin Periodontol*. 2013;40:1132-1139.
69. Rossell J, Puigdollers A, Girabent-Farrés M. A simple method for measuring thickness of gingiva and labial bone of mandibular incisors. *Quintessence Int*. 2015;46:265-271.
70. Mozzo P, Procacci C, Tacconi A, Tinazzi Martini P, Bergamo Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. *Eur Radiol*. 1998;8:1558-1564.
71. Barriviera M, Duarte WR, Januário AL, Faber J, Bezerra ACB. A new method to assess and measure palatal masticatory mucosa by cone-beam computerized tomography. *J Clin Periodontol*. 2009;36:564-568.
72. Alves PHM, Alves TCLP, Pegoraro TA, Costa YM, Bonfante EA, de Almeida ALPF. Measurement properties of gingival biotype evaluation methods. *Clin Implant Dent Relat Res*. 2018;20:280-284.

73. Orban B. Clinical and histologic study of the surface characteristics of the gingiva. *Oral Surg Oral Med Oral Patol*. 1948;1:827-841.
74. Pejčić AS, Obradović RR, Mirkovic DS. The width of the attached gingiva and its variability in people with healthy periodontal status. *Acta Stomatol Naissi*. 2017;33:1703-1717.
75. Bernimoulin JP, Son S, Regolati B. Biometric comparison of three methods for determining the mucogingival junction. *Helv Odontol Acta*. 1971;15:118-120.
76. Guglielmoni P, Promsudthi A, Tatakis DN, Trombelli L. Intra- and inter-examiner reproducibility in keratinized tissue width assessment with 3 methods for mucogingival junction determination. *J Periodontol*. 2001;72:134-139.
77. Bathia G, Kumar A, Khatri M, Bansal M, Saxena S. Assessment of the width of attached gingiva using different methods in various age groups: a clinical study. *J Indian Soc Periodontol*. 2015;19:199-202.
78. Hilming F, Jervoe P. Surgical extension of vestibular depth. On the results in various regions of the mouth in periodontal patients. *Tandlaegebladet*. 1970;74:329-343.
79. Mazeland GR. The mucogingival complex in relation to alveolar process height and lower anterior face height. *J Periodontal Res*. 1980;15:345-352.
80. Lee SP, Kim TI, Kim HK, Shon WJ, Park YS. Discriminant analysis for the thin periodontal biotype based on the data acquired from three-dimensional virtual models of Korean young adults. *J Periodontol*. 2013;84:1638-1645.
81. Ahmed AJ, Nichani AS, Venugopal R. An evaluation of the effect of periodontal biotype on inter-dental papilla proportions, distances between facial and palatal papillae in the maxillary anterior dentition. *J Prosthodont*. 2018;27:517-522.

How to cite this article: Malpartida-Carrillo V, Tinedo-Lopez PL, Guerrero ME, Amaya-Pajares SP, Özcan M, Rösing CK. Periodontal phenotype: A review of historical and current classifications evaluating different methods and characteristics. *J Esthet Restor Dent*. 2020;1–14. https://doi.org/10.1111/jerd.12661