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REVIEW ARTICLE

Gingival Thickness: Critical Clinical Dimension of Periodontium

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ABSTRACT

Clinical appearance of normal gingival tissue in part reflects the underlying structure of epithelium and lamina propria. It has been described that particular shape, topographical distribution, and width of gingival are clearly functions of presence and position of erupted teeth. Moreover, tooth shape seems to have an important impact on the clinical features of surrounding gingiva and probably also underlying tooth-supporting periodontal tissue. The thickness of masticatory mucosa was studied in a descriptive manner by conventional histology on cadaver jaws. Others assessed the mucosal thickness in edentulous patients using invasive method of injection needle, macroscopic measurement of histologic sections, a graduated periodontal probe or cephalometric radiographs. Noninvasive methods were performed with ultrasonic devices. A-mode ultrasonic device was used to measure tissue thickness in edentulous patients. B-mode was used to visualize soft and hard tissue relationships while also measuring soft tissue thickness. Among the various macroscopic features of gingiva, the gingival thickness (GT) is least discussed and not mentioned in the standard textbooks and journals. There are few terminologies which are not well defined in periodontal literature like periodontal phenotype, gingival phenotype, gingival architecture, gingival morphology, and GT; hence, this review article will put some light on these terminologies and literature review related to the clinical importance and relevance on masticatory mucosa thickness, chiefly on palatal mucosa and gingiva.

Keywords: Gingiva, Gingival thickness, Mucosal thickness, Peri-implant mucosa.

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INTRODUCTION

The gingiva (i.e., the marginal periodontium) is that portion of oral mucous membrane which in a complete posteruptive dentition of a healthy individual, surrounds the teeth, and is attached to alveolar processes. Clinical appearance of normal gingival tissue in part reflects the underlying structure of epithelium and lamina propria.[1] It has been described that particular shape, topographical distribution, and width of gingival are clearly functions of presence and position of erupted teeth. Moreover, tooth shape seems to have an important impact on the clinical features of surrounding gingiva and probably also underlying tooth-supporting periodontal tissue.[2]

It has been long known that clinical appearance of healthy marginal periodontium differs from subject to subject and even among different tooth types. Many features are genetically determined; others seems to be influenced by tooth shape, size, and position and biological phenomenon, such as growth or aging. It was observed that GT strongly depended on periodontal probing depth, width of gingiva, and tooth type.[1]

The inter- and intraindividual variation of gingival width has been subject of numerous investigations, whereas GT has commanded considerable attention only recently. In recent years, dimensions of different parts of masticatory mucosa, especially GT, have become a subject of considerable interest in Periodontics, both from an epidemiologic and a therapeutic point of view.

The hidden role of GT is being realized as the visible dimension wherein many of the clinical issues are dependent. There are several studies on GT, palatal thickness, and keratinized mucosa available in the literature. Its importance is multifaceted in the interdisciplinary treatment approaches, such as periodontics, restorative dentistry, prosthodontics, orthodontics, and implantology. Hence, in this paper, the thickness of masticatory mucosa (gingiva and palatal mucosa) is reviewed and its clinical relevance is discussed.

Terminologies

There are few terminologies which are not well defined in periodontal literature like periodontal phenotype, gingival phenotype, gingival architecture, gingival morphology, and GT. Differences between various terminologies are shown in Table 1. However, most often, the terms phenotype and biotype are used either for gingival width or thickness alone which is not ideal. Hence, it is recommended to use the appropriate term like GT or width according to the need of the study.

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Table 1: Terminologies used interchangeably in periodontal literature

Periodontal phenotype	*Periodontal biotype*	*Gingival thickness*
Term to address a common clinical observation of great variation in thickness and width of facial keratinized tissues	Periodontal biotype concentrates primarily on gingival contour/architecture, such as scalloped/flat along with description of gingival thickness.	• This term speaks about the volume of the gingiva present at particular site in a particular subject.
Width of keratinized tissue + thickness	Contour + thickness	• It mainly depends on the adjacent bone morphology and to a certain extent genetics play a role.

The term gingival or periodontal phenotype was recently coined by Muller and Eger[1] to address a common clinical observation of great variation in thickness and width of facial keratinized tissues. The thickness of masticatory mucosa and gingival width strongly depends on gender and different periodontal phenotype. According to Lindhe, the morphology/architecture of gingiva depends on various anatomic factors like:

- Dimension of the alveolar process
- Form/anatomy of the teeth
- Events during the tooth eruption
- Inclination and position of the erupted teeth.[3]

} determines the thickness of the gingiva directly or indirectly

Types of gingival architecture with the teeth and osseous form are shown in Table 2 and the characteristics of thin and thick gingiva are shown in Table 3.[4]

Table 2: Types of gingival architecture with the teeth and osseous form

	Pounced scalloped type	*Flat biotype*
Teeth	Long, slender, tapered	Square
Cervical convexity	Delicate	Pronounced
Free gingiva	Thin	Wide and voluminous
Buccal cortical wall	Thick	Thin with more vertical distance (>4 mm)

Table 3: Characteristics of thin and thick gingiva

Thick gingiva	*Thin gingival*
Flat soft tissue and bony architecture	Highly scalloped and bony architecture
Dense fibrotic soft tissue	Delicate friable soft tissue
Relatively large amount of attached gingival	Minimum amount of attached gingival
Thick underlying osseous form	Thin underlying bone characterized by bony dehiscence and fenestration
Relatively resistant to acute trauma and inflammation	Susceptible to trauma and inflammation
Reacts to disease with pocket formation and infrabony defect formation	Reacts to insults and disease with gingival recession
>2 mm	<0.5 mm

Histological Factors determining GT

The thickness of the gingiva depends on the thickness of the epithelium and the connective tissue (lamina propria). Dimensions of the interdental papilla also depend on epithelium, entire supra alveolar connective tissue (1 mm) (supra alveolar connective tissue is composed of mesodermal structures of the gingiva like cells, fibers, and blood vessels embedded in amorphous ground substance present coronal to the crest of the alveolar bone).[5]

Various methods to assess GT with their advantages and disadvantages are shown in Table 4.

Various studies done on GT or biotype are shown in Tables 5 and 6.

Clinical Importance of GT

Various studies have shown the clinical importance of thickness of gingiva for the evaluation of postoperative results as shown in Table 7.

DISCUSSION

Age

The younger age group of 14 to 21 years had significantly thinner palatal mucosa of 2.8 ± 0.3 than older age group of mean 3.1 ± 0.3 mm age 30 to 59 years.[25] Palatal mucosa was found thin in Younger age (16–30 years) ranging from 2 to 3.1 mm, while in older age group (31–54 years), it was thick ranging from 3.2 to 3.7 mm. The mean thickness of the gingiva midbuccally in the maxillary and mandibular arches ranged between 0.97 (±0.29) and 1.03 (±0.31) mm and between 0.93 (±0.37) and 1.07 (±0.40) mm at the interdental papilla in the older age group (25–38 years).[11]

Gender

Gender did not influence the thickness of hard palate or tuberosity;[6] females in the age range of 14 to 59 years had GT ranging from 2 to 3.6 mm, while males had 2.3 to 3.7 mm thick gingiva. In the age group of 14- to 21-year females, it was found to be 2 to 3.5 mm and for males, it was 2 to 3 mm. In the most elderly group, i.e., 30- to 59-year females, it was 2.3 to 3.7 mm and males had 2.7 to 3.6 mm thick gingiva.[10] In the age group 16 to 24 years and

Table 4: Various methods to assess gingival thickness

Methods	*Author*	*Advantages*	*Disadvantages*
Visual evaluation	Ochsenbein and Ross,[6] Seibert and Lindhe,[7] Olsson et al[2]	Simple, Noninvasive Easy to perform	Not reliable method as it cannot be used to assess the degree of gingival thickness
Probe transparency	Kan et al[8]	Simple	Objective method, difficulty in assessing pigmented gingiva
	Jung et al[9]	Easy to perform	
	Kan et al[10]	Minimally invasive	
Transgingival probing	Vandana and Savitha[11] Fu et al[12]	Simple	Invasive method
		Less technique sensitive Easy to perform No special equipment is required Good reproducibility and reliability Economical	Measurements can be affected by: precision of the probe, the angulation of the probe, and the distortion of the tissue during probing Time-consuming
Modified caliper	Kan et al[13]	Easy to use, reproducibility of readings Reliable	Invasive method, only be used at the time of surgery and cannot be used for pretreatment evaluation
Ultrasonic devices	Muller et al,[14] Kydd et al,[15] Vandana and Savitha,[11] Fu et al,[12] Kan et al[13]	Least invasive method and offers excellent validity and reliability	Not available commercially in India, difficult to determine the correct position for accurate measurement and successfully reproduce measurements
Cone beam computed tomography	Barriviera et al[16] Fu et al[12]	Noninvasive	Difficulty in observing soft tissue margins Image analysis is difficult, more objective method than direct measurement

Table 5: Studies related to thickness gingiva and palate (keratinized and/or masticatory mucosa) pertaining to dentate and edentulous subjects

Author	*Title of the article*	*Comments*
Kydd et al[15]	The thickness measurement of masticatory mucosa *in vivo*. • 12 sites • Age group: 24–41 years • Palatal mucosa • Ultrasonic transducer • Thickness = 3.9–4 mm	• The ultrasonic transducer was utilized to determine the resting thickness of oral mucosa at 12 sites in dentate subjects aged 24–41 years, and reported that the thickest palatal mucosa (3.9–4 mm) was at the third molar area. • Analysis of the movement of the denture foundation under function is very important for the construction of denture. For, this the thickness of masticatory mucosa gives the required quantitative information.
Goaslind[17]	Thickness of facial gingiva • 10 subjects • Facial gingiva • Transformer coupled to an oscillator and digital voltmeter • Free gingival thickness 1.56 mm + 0.39 • Attached gingival thickness averaged 1.25 mm + 0.42 • Total mean thickness for all areas measured was 1.41 mm	• Gingival thickness was measured in 10 subjects with healthy gingiva on the facial aspect of selected maxillary and mandibular teeth at the depth of the gingival sulcus and midway between the sulcus depth and mucogingival line. • Free gingival thickness averaged 1.56 mm + 0.39, attached gingival thickness averaged 1.25 mm + 0.42 and the total mean thickness for all areas measured was 1.41 mm. • Thickness in mandibular free and attached gingival and maxillary free gingiva increased from anterior to posterior. Thickness in maxillary attached gingival remained fairly constant. • Thickness measured at the depth of the sulcus was directly proportional to the free gingival width. • Thickness measured midway between sulcus depth and mucogingival junction was inversely proportional to attached gingival width.
Olsson and Lindhe[18]	Periodontal characteristics in individuals with varying form of the upper central incisors. • Maxillary incisors of 113 subjects • Clinical photographs	• It has been suggested that the variation in the morphology of the human periodontium may be related to the shape and form of the teeth. • The result from the analyses demonstrated that: • Subjects with a long-narrow form of the upper central incisors had experienced more recession of the gingival margin at buccal surfaces than subjects who had a short-wide tooth form; • There was a significant influence of the CW/CL ratio on the probing attachment level ($p < 0.05$) and the amount of gingival recession ($p < 0.01$) on buccal tooth surfaces.

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Author	*Title of the article*	*Comments*
Olsson et al[2]	On the relationship between crown form and clinical features of the gingiva in adolescents ▪ Maxillary front tooth segment 108 subjects ▪ Morphologic characteristics of tooth and free gingival thickness	• The results from the analyses demonstrated that individuals with a long-narrow form of the central incisors displayed, compared with individuals with a short-wide crown, form – A narrow zone of keratinized gingiva – Shallow probing depth, and – A pronounced "scalloped" contour of the gingival margin • There was no significant difference between groups long narrow and short wide with respect to the thickness of the free gingiva. • The regression analyses demonstrated that the thickness of the free gingiva in central incisors was significantly related to the width of the keratinized gingiva, the buccolingual width of the crown and the presence of an interproximal gingival groove. In lateral incisors, the thickness of the free gingiva was associated with the probing depth at the buccal surface. No single variable was significantly related to the thickness of the gingiva in canines.
Anderegg et al[19]	Gingiva thickness in guided tissue Regeneration and associated recession at facial furcation defects • 37 moderate-to-advanced adult periodontitis patients presenting with at least one mandibular or maxillary molar class I or II facial furcation involvement • Mid-facial tissue thickness was measured using calipers 5mm apical to gingival margin	The purpose of this study was to determine if the thickness of tissue used to cover the membrane influences postsurgery recession. Mid-facial presurgery recession was recorded from the cementoenamel junction to the free gingival margin at a reproducible point. Mid-facial tissue thickness was measured using calipers at a point 5 mm apical to the gingival margin of the mucogingival flap reflected at the time of guided tissue regeneration surgery. Two groups were made: 16 patients GT 1 mm 21 patients tissue thickness > 1 mm Sixteen (16) patients with tissue thickness 1 mm demonstrated a mean 2.1 mm increase in recession, while 21 patients with tissue thickness > 1 mm exhibited a mean 0.6 mm increase in recession. We conclude that there is less posttreatment recession ($p < 0.01$) for tissue thickness > 1 mm than tissue thickness < 1 mm. Hence, thickness of gingival tissue covering a membrane appears to be a factor to consider if posttreatment recession is to be minimized or avoided
Wennström et al[20]	Increased gingival dimensions. A significant factor for successful outcome of root coverage procedures? A 2-year prospective clinical study	• The aim of this study was to evaluate whether an increased thickness of the gingiva through the use of a free connective tissue graft, in conjunction with a coronally advanced flap procedure. • It was concluded that the two surgical procedures resulted in similar degree of root coverage and that changes of tooth brushing habits may be of greater importance than increased gingival thickness for long-term maintenance of the surgically established position of the soft tissue margin.
Studer et al[21]	The Thickness of Masticatory Mucosa in the Human Hard Palate and Tuberosity as Potential Donor Sites for Ridge Augmentation Procedures ▪ Bone sounding on 31 subjects ▪ Hard palate and tuberosity ▪ Fully dentate subjects	• Gender did not influence the thickness of masticatory mucosa, either in the hard palate or the tuberosity with the exception of the most distant line in the palate. Clinical transfer: • The mucosa was thickest at the mid-distal position of the tuberosity. In the hard palate, mucosa thickness increased with greater distances from the marginal gingiva. The mucosa over the palatal root of the maxillary first molar was significantly thinner than at all other positions in the hard palate. This represents an anatomical barrier in graft harvesting. It was concluded that two different regions may be defined for soft tissue graft harvesting from an anatomic point of view: (1) In the canine-premolar region rather wide and shallow grafts may be harvested. This region extends distally to the first palatal molar root with a significantly thinner mucosa. (2) The tuberosity revealed a significantly more soft tissue thickness in comparison with the hard palate. This region allows the harvesting of deeper grafts, but graft size is limited by the width of keratinized tissue.
Muller et al[14]	Ultrasonic determination of thickness of masticatory mucosa: a methodological study. ▪ Animal study (pigs) ▪ Attached gingiva ▪ Ultrasonic device and endodontic reamer	Thickness of attached gingiva was measured using a commercially available A-mode, intraoral ultrasonic device and reported that the validity and reliability of measuring gingival thickness with the ultrasonic device was found to be excellent. They also assessed the gingival thickness in half mandibles of freshly slaughtered 6-month-old pigs using an endodontic reamer for transgingival probing followed by an ultrasonic device, (SDM, Krupp corp Essen Germany) and reported an excellent validity of the result of the ultrasonic device.

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Author	Title of the article	Comments
Müller et al[22]	Thickness of masticatory mucosa ▪ 19–30 years ▪ Palatal + facial gingiva ▪ Ultrasonic measuring device.	The aim of the present study was to assess thickness of all parts of the masticatory mucosa by using an ultrasonic measuring device. Female volunteers had significantly thinner mean masticatory mucosa than males (p 0.01). Mean thickness of facial gingiva ranged between 0.7 mm at canines in the maxilla and central incisors in the mandible and 2.3 mm at 3rd molars in the mandible. In the mandible, thickness of lingual gingiva ranged between 0.9 mm at lateral incisors and 2.3 mm at 3rd molars. Interdental gingival ranged between 1.0 and 2.1 mm. With 3 mm or more, on average, palatal masticatory mucosa was thickest in the 3rd molar region and at 2nd premolars at more central locations. Two regions with comparatively thin palatal mucosa of about 2 mm were identified, namely (i) at central and lateral incisors and (ii) at the prominence of the palatal roots of 1st and 2nd molars. The thickest tissue with more than 4 mm, on average, was observed in the tuberosity and retromolar regions. Clinical transfer: Considerable intra- as well as interindividual variation of thickness of masticatory mucosa could be observed. According to differences in thickness of facial and interdental gingiva, it appears that lining is also an important function.
Müller and Heinecke[23]	Masticatory mucosa in subjects with different periodontal phenotypes ▪ Thickness + width ▪ Cluster analysis of standardize parameters	The aim of the present investigation was to study thickness of masticatory mucosa and gingival width in subjects with different periodontal phenotypes.Masticatory mucosa in subjects with different periodontal phenotypes Women had considerably thinner palatal mucosa than men. Thickest tissue was found in the premolar region, whereas the mucosa over the root prominence of the first molar represented an anatomical barrier for graft harvesting. Thickness of masticatory mucosa strongly depends on gender and the periodontal phenotype.
Wara-aswapati et al[24]	Thickness of Palatal Masticatory Mucosa Associated with Age ▪ 14–59 years ▪ Younger age group (age 14–21 years) mean age of 16.8 years ▪ Older age group (age 30–59 years) mean age of 38.7 years. ▪ Palatal masticatory mucosa ▪ Bone sounding	The mean thickness of palatal masticatory mucosa ranged from 2.0 to 3.7 mm. The younger age group had significantly thinner mucosa (mean 2.8 ± 0.3 mm) than the older age group (mean 3.1 ± 0.3 mm). Females had thinner mucosa than males in the same age group, but the difference was not statistically significant. Overall, the thickness of palatal mucosa increased from the canine to second molar areas and in the sites furthest from the gingival margin toward the midpalate (with the exception of the first molar area, where significantly decreased thickness was observed). Clinical transfer: Within the limits of the present study, the canine and premolar areas appear to be the most appropriate donor site for grafting procedures in both young and adult individuals. The subepithelial connective tissue graft procedure can be considered as a treatment modality in young patients, since a sufficient volume of donor tissue can be obtained from the hard palate area. Other factors that may influence the thickness of palatal mucosa, such as racial and genetic factors and body weight need to be further investigated.
Müller and Eger[25]	Masticatory mucosa and periodontal phenotype: a review	In recent years, the dimensions of different parts of the masticatory mucosa have become the subject of considerable interest in periodontics from both an epidemiologic and a therapeutic point of view. In the present article, the clinical relevance of the thickness of masticatory mucosa for the development of gingival recessions, surgical root coverage, as well as graft harvesting was reviewed. The concept of different periodontal phenotypes has recently been substantiated by experimental evidence using a novel, commercially distributed, ultrasonic measuring device. Based on observations made in a series of investigations, it has become clear that individuals with thin and vulnerable gingival tissue prone to the development of recession often also present with thin palatal mucosa that might not be very suitable for obtaining connective tissue of proper thickness for plastic periodontal surgery. Periodontal phenotypes are closely associated with, and are in fact an expression of, the so-called biologic width, which should be considered during subgingival placement of restorations in particular. Thus, a detailed analysis of the thickness of the masticatory mucosa may be necessary in several clinical situations.

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Author	*Title of the article*	*Comments*
Vandana and Savitha[11]	Comparative assessment of gingival thickness using ultrasonography and transgingival probing method • TGP and USG method • Periodontally healthy subjects 16–38 years: 16 males and 16 females • The gingival enlargement group 18–45 years: 5 males and 8 females	Comparison of TGP *vs* USG was done on periodontally healthy subjects and with gingival enlargement midbucally and in the interdental papilla. In periodontally healthy subjects 16–38 years; 16 males and 16 females showed significantly higher values in TGP method (midbucally, 1.08 ± 0.42; interdental papilla 1.26 ± 0.60) than USG method (midbucally 0.86 ± 0.33; interdental papilla 0.77 ± 0.38) In the gingival enlargement group 18–45 years 5 males and 8 females comparison of TGP *vs* USG measurements (mm) showed significantly higher values in TGP method (midbucally, 1.58 0.77; interdental papilla 2.81 ± 1.65) than USG method (midbucally 1.05 ± 0.50; interdental papilla 0.92 ± 0.83)
Müller and Könönen[26]	Variance components of gingival thickness • 33 females, 18–23 years • Facial gingiva in gingivitis • Ultrasound technology • 0.93 ± 0.02 mm	The aim of the present study was to investigate variance components of facial gingival thickness in young adults with mild gingivitis. The gingival thickness without any explanatory variable revealed an intercept (mean) of 0.93 ± 0.02 mm. Gingival thickness is mainly associated with tooth-related variables. Bleeding tendency is higher if gingiva is thin. Subject variability related to periodontal phenotype may add to the total variance, however, to a very low extent.
Vandana and Savitha[11]	Thickness of gingiva in association with age, gender and dental arch location. 16 males and 16 females 16–38 years. • The younger age group (16–24 years) • The older group (25–38 years) • maxillary and mandibular anteriors • transgingival probing • mean thickness	The purpose of this study was to determine the thickness of facial gingiva among Indians and its association with age, gender and dental arch. It was observed that the younger age group had significantly thicker gingiva than that of the older age group. The gingiva was found to be thinner in females than males and, in the mandibular arch than the maxilla. In the present study, it was concluded that gingival thickness varies according to age, gender and dental arch
Savitha and Vandana[27]	Comparative assessment of gingival thickness using transgingival probing and ultrasonographic method. • 32 subjects • 16 males and 16 females • 16–38 years • Central incisor lateral incisor and canine • Transgingival probing and ultrasonographic (mode A) method • Thickness in health • Thickness in disease	In the present study an attempt has been made to compare the two methods of assessing gingival thickness, i.e., transgingival probing and ultrasonographic method and also assess the gingival thickness in relation to central incisor lateral incisor and canine in Indian population. The gingival thickness was assessed in patients with healthy gingiva by both the methods. It was observed that transgingival probing method significantly overestimated the thickness of gingiva than the ultrasonographic method and the thickness of gingiva varies with morphology of the crown. It was concluded that compared with transgingival probing ultrasonographic method assesses gingiva thickness more accurately, rapidly and atraumatically.
De Rouck et al[28]	The gingival biotype revisited: transparency of the periodontal probe through the gingival margin as a method to discriminate thin from thick gingiva. • 100 periodontally healthy subjects • Transparency of the periodontal probe through the gingival margin while probing the buccal sulcus. • Thin clear gingiva in 1/3rd of the subjects • Thick clear gingiva in 2/3rd of the subjects	Aim: To detect groups of subjects in a sample of 100 periodontally healthy volunteers with different combinations of morphometric data related to central maxillary incisors and surrounding soft tissues. The present analysis, using a simple and reproducible method for GT assessment, confirmed the existence of gingival biotypes. A clear thin gingiva was found in about 1/3rd of the sample in mainly female subjects with slender teeth, a narrow zone of keratinized tissue and a highly scalloped gingival margin corresponding to the features of the previously introduced "thin-scalloped biotype" (cluster A1). A clear thick gingiva was found in about 2/3rd of the sample in mainly male subjects. About half of them showed quadratic teeth, a broad zone of keratinized tissue and a flat gingival margin corresponding to the features of the previously introduced "thick-flat biotype" (cluster B). The other half could not be classified as such. These subjects showed a clear thick gingiva with slender teeth, a narrow zone of keratinized tissue and a high gingival scallop (cluster A2).
Kan et al[13]	Gingival biotype assessment in the esthetic zone: visual *vs* direct measurement. • Facial gingival biotype	The authors reported a statistically significant difference between visual assessment and both the periodontal probe and the tension-free caliper; however, there was no statistically significant difference when comparing the periodontal probe assessment and the tension-free caliper.

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Author	Title of the article	Comments
	• Visual evaluations, • Periodontal probe, and • A tension-free caliper	Based on these results, a periodontal probe in the sulcus is an adequately reliable and objective way to evaluate tissue thickness, whereas visual evaluation of the gingival thickness by itself is not as reliable as the periodontal probe or the tension-free caliper.
Cuny-Houchmand et al[29]	Gingival biotype assessment: visual inspection relevance and maxillary *vs* mandibular comparison • 53 patients • Visual inspection and photographic documents • One of three biotypes: • Thin-scalloped, • Thick-scalloped, or Thick-flat gingival biotype	This clinical study was aimed at evaluating the accuracy of gingival visual inspection procedures during clinical examination and determining whether differences existed between the maxillary and mandibular gingival biotypes. Based on the above results, it can be concluded that a simple visual inspection is not effective for the identification of gingival biotype. Furthermore, evidence suggests that a difference of biotype between the maxilla and the mandible in the same patient is conceivable. Therefore, orthodontic clinical examination should incorporate a reproducible method of determining the individualized gingival biotype for each group of teeth that will be moved.
Stein et al[30]	The gingival biotype: measurement of soft and hard tissue dimensions—a radiographic morphometric study • 60 periodontally healthy subjects • Central maxillary incisor • CW/CL ratio examined • Probe transparency (TRAN) • Radiographs were taken	Gingival biotypes have been reported to influence the outcome of restorative therapies. The aim of this study was to evaluate the correlation of different morphometric parameters with the thickness of the buccal gingiva and alveolar bone at different apicocoronal levels. Clinical parameters included the crown width/crown length ratio (CW/CL), gingival width (GW), gingival scallop (SC) and transparency of the periodontal probe through the gingival sulcus (TRAN). Gingival and alveolar bone dimensions were assessed on parallel profile radiographs. Crown width/crown length ratio and GW could represent surrogate parameters to anticipate the gingival thickness at the cementoenamel junction, whereas CW/CL might also be an indicator for alveolar bone crest thickness. Periodontal probing has a limited prognostic value for these tissue dimensions.
Hwang and Wang[31]	Flap thickness as a predictor of root coverage: a systematic review	Thick gingival tissue eases manipulation, maintains vascularity, and promotes wound healing during and after surgery. A few recent case reports correlate greater flap thickness to mean and complete root coverage after mucogingival therapy for recession defects. The aim of this systematic review is to appraise the current literature on this subject and to combine existing data to verify the presence of any association between gingival thickness and root coverage outcomes. A significant moderate correlation occurred between weighted flap thickness and weighted mean root coverage and weighted complete root coverage ($r = 0.646$ and 0.454 respectively). According to Mann–Whitney analysis, a critical threshold thickness >1.1 mm existed for weighted mean and complete root coverage ($p < 0.02$). The type of treatment rendered also influenced root coverage. Further simple linear regression revealed a high correlation between weighted thickness and weighted mean root coverage in connective tissue grafting and guided tissue regeneration ($r = 0.909$ and 0.714 respectively) but not coronally advanced flap therapy. Study score and follow-up time did not affect the percentage of root coverage. Conclusion: Within the limits of this review, a positive association exists between weighted flap thickness and mean and complete root coverage.
Kolliyavar et al[32]	Determination of thickness of palatal mucosa • Palatal mucosa • Younger age (16–30 years)—thin gingiva=2 to 3.1 mm • Older age group (31–54 years) = 3.2 to 3.7 mm • Periodontal probe UNC 15 with stopper	The palatal masticatory mucosa is widely used as a donor material in periodontal plastic surgery. The thickness of graft tissue is an important factor for the graft survival. The purpose of this study was to determine the thickness of palatal mucosa by a bone sounding technique. The association of age and gender with the thickness of palatal mucosa was also examined. The younger age group had thinner mucosa ranged from 2 to 3.1 mm in thickness than the older age group which ranged from 3.2 to 3.7 mm. In the same age group, females had thinner mucosa than males in the same age group. The mean thickness of palatal masticatory mucosa ranged from 2.5 to 3.7 mm. Conclusion: The younger subjects had thinner mucosa than older subjects. The canine and premolar areas appeared to be the most appropriate donor site for grafting procedures.

Table 6: Studies related to keratinized mucosa pertinent to implant and prosthetic dentistry

Author	*Title of the article*	*Excerpts*
Zigdon and Machtei[33]	The dimensions of keratinized mucosa around implants affect clinical and immunological parameters • Width + thickness • Width = 0–7 mm (mean 2.52) • Thickness = 0.38–2.46 (mean 1.11–0.4) • Mucosal recession = 0.62 mm range 0–3 mm	To investigate the association between keratinized mucosa (KM) width and mucosal thickness (MTh) with clinical and immunological parameters around dental implants. A wider KM band was also associated with a greater PD (3.13 mm) compared with a narrow band (2.66 mm, p 0.04). Similarly, a thick mucosa (>1 mm) was associated with lesser recession compared with a thin (<1 mm) mucosa (0.45 and 0.9 mm respectively, p 0.04). The KM around dental implants affects both the clinical and the immunological parameters at these sites. These findings are of special importance in the esthetic zone, where thin and narrow KM may lead to a greater MR.
Bouri et al[34]	Width of Keratinized Gingiva and the Health Status of the Supporting Tissues Around Dental Implants • Width • Radiographic bone loss • Narrow zone (<2 mm) of keratinized mucosa	This cross-sectional study was performed to determine whether an association exists between the width of keratinized mucosa and the health of implant-supporting tissues. Radiographic bone loss was significantly higher for those implants with a narrow zone (< 2 mm) of keratinized mucosa. Implants with a narrow zone of keratinized mucosa also were more likely to bleed upon probing, even after adjusting for plaque index, smoking, thickness of the gingiva, and time since implant placement Significant independent association also was found between the width of keratinized mucosa and radiographic bone loss in favor of wider zone of keratinized mucosa. Increased width of keratinized mucosa around implants is associated with lower mean alveolar bone loss and improved indices of soft tissue health (cross-sectional study).
Linkevicius et al[35]	The influence of soft tissue thickness on crestal bone changes around implants: a 1-year prospective controlled clinical trial. • A (thin mucosa) was 1.61 ± 0.24 mm (SE; 0.9–3.3 mm) on the mesial • 1.28 ± 0.167mm (0.8–2.1 mm) on the distal	The aim of this clinical trial was to evaluate the influence of gingival tissue thickness on crestal bone loss around dental implants after a 1-year follow-up. Mean bone loss around the test implants in group I (thin mucosa) was 1.61 ± 0.24 mm (SE; 0.9–3.3 mm) on the mesial and 1.28 ± 0.167 mm (0.8–2.1 mm) on the distal. Mean bone loss in test group II (thick mucosa) implants was 0.26 ± 0.08 mm (0.2–0.9 mm) on the mesial aspect and 0.09 ± 0.05 mm (0.2–0.6 mm) on the distal aspect. Mean bone loss around control implants was 1.8 ± 0.164 mm (0.6–4.0 mm) and 1.87 ± 0.166 mm (0.0–4.1 mm) on the mesial and distal aspects respectively. Analysis of variance revealed a significant difference in terms of bone loss between test A (thin) and test B (thick) groups on both the mesial and the distal. Initial gingival tissue thickness at the crest may be considered as a significant influence on marginal bone stability around implants. If the tissue thickness is 2.0 mm or less, crestal bone loss up to 1.45 mm may occur, despite a supracrestal position of the implant–abutment interface.
Fu et al[12]	Tissue Biotype and Its Relation to the Underlying Bone Morphology ▪ Cone beam computed tomography (CBCT)	Tissue biotypes have been linked to the outcomes of periodontal and implant therapy. The purpose of this study is to determine the dimensions of the gingiva and underlying alveolar bone in the maxillary anterior region and to establish their association. Clinical and CBCT measurements of both soft tissue and bone thickness were subsequently compared and correlated. No statistically significant differences were observed between the clinical and CBCT measurements of both soft tissue and bone thickness except the palatal soft tissue measurements. The labial gingival thickness was moderately associated with the underlying bone thickness measured with CBCT ($R = 0.429$; $p < 0.05$). Gingival recession was not associated with the thickness of both labial gingiva and bone. CBCT measurements were an accurate representation of the clinical thickness of both labial gingiva and bone. In addition, the thickness of the labial gingiva had a moderate association with the underlying bone radiographically

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Author	Title of the article	Excerpts
Lee et al[36]	Soft tissue biotype affects implant success	The influence of tissue biotype in natural dentition is already well demonstrated in the literature, with numerous articles showing that thicker tissue is a preferred biotype for optimal surgical and prosthetic outcomes. In this same line of thought, current studies are directed to explore whether mucosal thickness would have similar implications around dental implants. The purpose of this review was to investigate the effects of soft tissue biotype in relation to success of implant therapy. The influence of tissue biotype was divided into three main categories: its relationship with peri-implant mucosa and the underlying bone, immediate implant placement, and restorative outcomes. Soft tissue biotype is an important parameter to consider in achieving esthetic implant restoration, improving immediate implant success, and preventing future mucosal recession.

Table 7: Clinical importance of gingival thickness

Clinical application	Authors, year, and conclusion of the study
Gingival thickness and labial plate thickness	For patients with a thin gingival biotype, extreme care should be taken during extraction to prevent labial plate fracture. Cook et al[37] evaluated the correlation between labial plate thickness and thin or thick gingival biotypes—using information obtained from cone beam computed tomography (CBCT), diagnostic impressions, and clinical examinations of maxillary anterior teeth—and concluded that a significant association existed between gingival biotype and labial plate thickness.
Gingival thickness and postorthodontic mucogingival problems	Mucogingival problems may result from orthodontic movement of teeth away from the alveolar process, particularly among patients with thin periodontium.[38,39]
Gingival thickness and Schneiderian membrane thickness	The most common complication during sinus graft procedures is perforation of the sinus membrane. This condition may occur after the sinus floor is accessed through the lateral wall or the ridge crest.[40-42] Clinical observations have prompted clinicians to suggest a correlation between the sinus membrane thickness and the risk of perforation.[43,44] Aimetti et al[45] took maxillary mucosal biopsies from the sinus floor during otorhinolaringologic surgical interventions, and measured gingival thickness in the area of the maxillary anterior teeth. The authors reported that the average thickness of the Schneiderian membrane was 0.97 ± 0.36 mm. Patients with thick gingiva had a sinus mucosa that was 1.26 ± 0.14 mm thick, compared with 0.61 ± 0.15 mm thickness among patients with thin gingiva. The results showed that gingival thickness is a reliable factor for predicting sinus membrane thickness.[45]
Tissue thickness periodontal flap surgery and root coverage	Tissot and Sullivan[46] did a study on dogs to find the differences between the partial thickness and full thickness flap and concluded that the circulatory embarrassment of mucogingival flaps was greater after partial thickness compared with full thickness dissection. During full thickness flap elevation, it is not unreasonable to consider that thin flaps are at greater risk than thick (> 1 mm) flaps for ischemia and necrosis due to their relatively thinner tissue component. Anderegg et al[19] did a human study on furcation treatment indicating the thin and thick gingival thickness consideration concluded that the thicker the connective tissue, better the potential circulatory part and the greater chance of flap survival. Pressure of the flap again the guided tissue regeneration (GTR) membrane or tension in flap as a result of attempting to completely cover the membrane may also compromise blood supply to the flap margin. The blood supply in thin flaps is more likely to be embarrassed by tension than in thicker flaps of equal mobility. In addition to the effects of routine flap manipulation, flap margins can be inadvertently thinner during flap incisions and increase risk of postsurgery recession. This effect might be magnified in thinner, more delicate tissue. During GTR, if thin soft tissue covers the defect, recession may occur with greater frequency and magnitude than thinker flap presurgically. The thin flaps with thin connective tissue are at greater risk for inflammation-induced postsurgery recession than thick flap. Mormann et al[47] showed in a study on free gingival autograft thickness concluded that thin free gingival autograft with a thin connective tissue base undergoes more postsurgery shrinkage than thicker grafts. According to McFall,[48] tissue thickness in the recipient site and the donor site are key factors in how mucogingival defects are treated. In cases involving root coverage surgeries, a flap thickness of 0.8 to 1.2 mm produced more predictable outcomes. An initial gingival thickness was found to be the most predictable factor for predicting the success of complete root coverage procedures.[49] There is a correlation between flap thickness and complete root coverage.[31]

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Clinical application	*Authors, year, and conclusion of the study*
Palatal tissue thickness and its relationship with greater palatine artery	Cho et al[50] did a study aimed to measure the thickness of the epithelium and lamina propria of the palatal mucosa and to elucidate the location of the greater palatine artery to provide the anatomical basis for subepithelial connective tissue grafting. 32 maxillary specimens, canine distal area to the first molar distal area, samples embedded in paraffin and stained with hematoxylin-eosin. The thickness of the epithelium and lamina propria of the palatal mucosa was measured at three positions on these specimens, starting from 3 mm below the alveolar crest and in 3-mm intervals. The location of the greater palatine artery was evaluated by using image-processing software. The mean epithelial thickness decreased significantly in the posterior teeth; it was 0.41, 0.36, 0.32, and 0.30 mm in the canine, first premolar, second premolar, and first molar distal areas respectively. The lamina propria was significantly thicker in the canine distal; it was 1.36, 1.08, 1.09, and 1.05 mm respectively. The mean length from the alveolar crest to the greater palatine artery increased toward the posterior molar; it was 7.76, 9.21, 10.93, and 11.28 mm respectively. The mean depth from the surface of the palatal mucosa to the greater palatine artery decreased from the canine distal to the first premolar distal but increased again toward the posterior molar; it was 3.97, 3.09, 3.58, and 5.50 mm respectively. Detailed histological assessments of the lamina propria of the palatal mucosa and the greater palatine artery are expected to provide useful anatomical guidelines for subepithelial connective tissue grafting.
Gingival thickness and ridge preservation	A thin gingival biotype is associated with a thin alveolar plate; more ridge remodeling has been found in this biotype when compared with thick periodontal biotype. Ridge preservation should be considered for most thin biotype cases. Preservation of alveolar dimensions, (such as socket preservation or ridge preservation techniques after tooth extraction) is critical for achieving optimal esthetic results in thin biotypes; atraumatic extraction also may be necessary.[51-53]
Masticatory mucosa thickness and stability of complete dentures	The thickness measurements were taken from 21 oral sites in 100 edentulous patients, by means of 20 MHz B-mode ultrasonic equipment. The average thickness of the masticatory mucosa ranged from 1.92 to 2.38 mm at the upper edentulous ridge and from 1.45 to 1.58 mm at the lower edentulous ridge. The center of the palate had the thinnest mucosa and the lateral area of the palate had the thickest among all the measuring points. As the degree of ridge reduction increased, a decrease in the mucosal thickness was found. At four of the 21 measuring sites, male patients had significantly thicker mucosa than did females.[54]
Tissue thickness in implant treatment planning	Studies have examined how mucosal thickness and biologic width affect crestal bone loss around implants.[54,55] Animal study by Berglundh and Lindhe[56] concluded that thin gingival tissue can lead to marginal bone loss during formation of the peri-implant biologic width. Another histologic study by Huang et al[57] reported that implant sites with thin mucosa were prone to angular bone defects, while stable crestal bone was maintained in implants surrounded by thick mucosa. According to Abrahamsson et al,[58] thick tissues (i.e., ≥2.5 mm) can avoid significant crestal bone recession; however, the authors recommend avoiding supracrestal placement of implants if an implant is surrounded by a thin biotype. Gingival recession is one of the most common complications resulting from single anterior tooth implant placement.[59] Gingival biotype is a diagnostic key for predicting the esthetic success of an implant.[60] According to Evans and Chen,[61] gingival recession increases in patients with thin biotypes immediately after single-implant restorations. Furthermore, papilla between immediate single implants and adjacent teeth is significantly associated with a thick gingival biotype. Patients with thick-flat mucosa tended to maintain the implant papillae height.[62] Dramatic alveolar resorption in the apical and lingual direction is possible in patients with a thin biotype. The loss of peri-implant tissues may result in facial plate loss, with the implant taking on a grayish color; additional bone and soft tissue grafting surgeries may be necessary in such cases. Immediate placement of an implant in a thick gingival biotype offers predictable results.[63] An *in vitro* study by Jung et al[64] evaluated different materials (titanium, ceramized titanium, zirconium, and ceramized zirconium) 10 pig maxillae were used, and the palatal area was chosen as the test region. To simulate different mucosa thicknesses, connective tissue grafts, 0.5 and 1.0 mm thick, were harvested from three additional jaws. Defined mucosa thicknesses were created by placing the grafts under a palatal mucosa flap. Tissue color was measured by a spectrophotometer. All of the materials changed the color of the thin (1.5 mm) mucosa, with titanium producing the greatest change. In normal (2.0 mm) mucosa, only titanium altered the color. In thick (3.0 mm) mucosa, no changes were observed from any of the materials. The results suggest that it is preferable to use pillars of zirconium for thin peri-implant mucosa, to avoid color changes of the mucosa.[64]

25 to 38 years, the mean thickness of the gingiva midbuccally in the maxillary and mandibular arches ranged between 0.97 ± 0.29 and 1.03 ± 0.31 mm, and between 0.93 ± 0.37 and 1.07 ± 0.40 mm at the interdental papilla in the older age group (25–38 years). On comparison of GT between males and females at both sites, female volunteers had thinner gingiva than males; hence, the thickness of masticatory mucosa depends on gender and periodontal phenotype. The thickness of gingiva in the maxillary midbuccal region in males was 0.99 ± 0.28 and in females, it was 1.00 ± 0.35, and in mandibular midbuccal region in males and females, it was 1.11 ± 0.35 and 1.02 ± 0.33 respectively.[11]

Areas of Thick and Thin Palatal Mucosa

Thickness of palatal mucosa was 3.9 to 4 mm at the 3rd molar area, using ultrasonic transducer[15]; the palatal mucosa increased in size with greater distance from the marginal gingiva and the palatal mucosa of the maxillary I molar was significantly thinner than all the other positions in the hard palate[21]; the mean palatal mucosa ranged from 2.0 to 3.7 mm overall, palatal musical thickness increased from canine to second molar areas and in the midpalate away from gingival margin.[24] On comparison between the maxillary and the mandibular arch at the midbuccal and interdental papillary region, the mandibular arch showed a thicker gingiva both midbuccally (1.07 mm) and in the interdental papillary region (1.13 mm) compared with the maxillary arch.[11]

CONCLUSION

Measurement of gingival dimension is clinically meaningful for both academicians and periodontists. Those academicians or clinicians who record GT measurement regularly could understand the outcome measures meaningfully. The diagnostic ability of GT measurement is commendable to distinguish bony and gingival enlargement. Considering the approximate GT of 1 mm, the transgingival probing determines gingival enlargement if GT measures more than 1 mm. In case of bone enlargement, the GT would measure 1 mm or even less. Depending on the clinical situation, bone or gingiva alone or combination of bone and gingival enlargement could be ascertained clinically by careful transgingival probing.

The prognostic ability of GT measurement is also appreciable in inflammatory-induced clinical changes as well as those induced due to fibrosis. A simple method of transgingival probing is cost-effective and dependable, although arduous and time-consuming when compared with the assessment of gingival crevicular fluid markers to assess to prognosis which can be reserved for unresponsive cases or those due to systemic causes.

It should be mandatory to record GT for all periodontal surgical procedures as the common outcome, such as recession depends on the GT. Along with recording of color, consistency, texture, position of gingiva, GT measurement is a useful simple tool for disease and treatment outcome measurement.

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