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Original Article

Revisiting the Measurement of Keratinized Gingiva: A Cross-Sectional Study Comparing an Intraoral Scanner with Clinical Parameters

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Abstract

The aim of this study was to investigate the relationships between gingival thickness (GT) and keratinized gingiva width (KGW), papilla height (PH), and crown ratio (CR) by employing transgingival probing and an intraoral scanner (IOS). This cross-sectional study examined 360 maxillary anterior teeth from 60 patients. GT was assessed using transgingival probing with an endodontic spreader. KGW, CR, and PH were measured using an IOS. One-way analysis of variance, the Student's *t*-test, and Spearman correlation coefficients were employed for statistical analysis. Higher GT was significantly associated with thinner KGW in the central region (*P*=0.019). There was no statistically significant difference in GT between teeth (*P*=0.06). PH was lower in lateral teeth than in canines (*P*=0.047), with a PH of 2.99 mm in lateral teeth. The KGW was narrower in canines than in central teeth (*P*=0.007). A moderate correlation was observed between KGW and PH in the central region (*P*=0.01), while a weak negative correlation was found between KGW and CR (*P*=0.043). A moderate negative correlation was found between GT and KGW, as well as between PH and KGW in central teeth. In contrast, a weak negative correlation existed between CR and KGW. The PH (2.99 mm) was lower in lateral teeth than in canines. The traditional paradigm, which suggests a positive correlation between KGW and GT, was re- evaluated by measuring KGW using an IOS.

Key words: Crown, Dental papilla, Diagnosis, Gingiva, Periodontics, Phenotype

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Introduction

Determining the qualitative and quantitative properties of periodontal tissues is crucial for estimating the outcomes of surgical and non-surgical periodontal therapies [1]. Various terms, such as biotype, phenotype, or morphotype, are used in the literature. However, the World Workshop of Periodontology in 2017 established "phenotype" as the standard terminology, replacing "biotype" [2]. Periodontal phenotype characteristics not only influence the outcomes, but also the progression or development of disease, as well as the type of treatment [3, 4]. Furthermore, a detailed evaluation of the periodontal phenotype is essential for achieving esthetic results in implant and restorative treatments, as well as periodontal surgery [5, 6].

Gingival thickness (GT) and keratinized gingiva width (KGW) are significant components of the periodontal phenotype [2]. The presence of marginal inflammation, bleeding on probing, and gingival recession are related to GT and KGW, making it essential to assess these parameters accurately before planning periodontal treatment [4]. GT is the most prominent aspect of the gingival phenotype and has a strong connection to gingival recession [6-8]. GT is classified as thin if the thickness is less than 1 mm and thick if the thickness is greater than 1 mm [9]. The literature suggests that gingival recession is less commonly observed after regenerative periodontal procedures when the gingiva is thick (greater than 1 mm), and a GT of 1.1 mm is a critical threshold for complete root coverage in mucogingival surgery [6, 9]. Therefore, understanding GT is crucial for guiding treatment. The keratinized mucosa is essential for periodontal stability and proper periodontal care or hygiene. When the KGW is less than 2 mm, plaque accumulation and a tendency for inflammation occur excessively [10].

Within the realm of esthetic-driven dentistry, the height of the gingival papilla (PH) and the crown ratio (CR) are crucial parameters, especially in the anterior region [6, 11]. The apicocoronal dimension of the papilla, which is closely associated with the occurrence of black triangles, is a significant parameter that warrants thorough examination [12]. Consequently, from both esthetic and functional standpoints, the clinical assessment of these parameters serves as a foundation for periodontal treatments, as well as orthodontic, implant surgery, and prosthetic restorations [3].

Several methods have been explored for the quantitative or qualitative evaluation of the gingival phenotype, including transgingival probing [8, 13], periodontal probe transparency [6, 7], ultrasound [7, 14], and the use of an intraoral scanner (IOS) [1, 15]. Among the methods for GT assessment, transgingival probing is considered one of the most objective and consistently accurate techniques, as it relies on direct measurements [7, 9]. Another approach involves visually inspecting the transparency of a periodontal probe inserted into the gingival sulcus; however, this method only offers information on whether the biotype is thin or thick, rather than providing a quantitative assessment [7, 9]. Direct measurement using an endodontic file, periodontal probe, or acupuncture needle, referred to in the literature as “transgingival sounding” or “transgingival probing,” is considered the gold standard [3, 7, 8].

In the literature, methods for determining KGW have included the use of periodontal probes and IOS [15, 16, 17]. The reliability of IOS has been shown to be superior to periodontal probes for measuring KGW due to the lower repeatability of probe placement and angulation [15]. Consequently, this study investigated KGW, PH, and CR using an IOS, while GT was assessed using the transgingival probing method. Previous studies have examined the relationship between GT and clinical parameters using various methodologies, yielding conflicting results [11, 13, 16- 21]. Technological advancements in digital dentistry have led to the adoption of digital measurements in diverse clinical procedures. In this context, high-resolution clinical images have also been utilized for evaluating KGW in the literature [20]. The aim of our study was to investigate the relationships between GT, KGW, PH, and CR using an IOS. Our null hypotheses were (1) that there would be no correlations between GT, KGW, PH, and CR, and (2) that there would be no difference in these parameters among the maxillary anterior teeth.

Materials and Methods

The protocol for this cross-sectional study was approved by the Akdeniz University Clinical Research Ethics Committee (protocol number: 70904504/28). Both written and oral informed consent were obtained for our study. This research was conducted in compliance with the guidelines set forth in the Declaration of Helsinki.

Population of the study

To determine the sample size, a power analysis was conducted using G*Power 3.1 software (Heinrich-Heine-Universität, Düsseldorf, Germany), with an effect size of 1.50 [6], a confidence level of 0.05, and a power of 95%. The required minimum sample size was 43 samples for each tooth. For this study, 60 patients (30 women and 30 men, aged between 19 and 23 years, with a mean age of 20.3 years) were enrolled. These patients were referred to the university dental clinic for routine dental examinations without any specific dental complaints between April and May 2022. All participants were native Turkish speakers to eliminate the influence of ethnic origin. A total of 360 maxillary anterior teeth were examined. The study’s inclusion criteria were patients in good systemic health, with no gingival recession, no dental complaints, non-smokers, not taking medications that could affect gingival tissue (e.g., cyclosporine, phenytoin), and no crowns, veneers, fillings, or caries in maxillary anterior teeth (including the first maxillary premolar). Patients with an Angle class I molar relationship, normal overjet and overbite, no previous periodontal surgery or orthodontic treatment, no misaligned dental arch, crowding, open bite or crossbite, and no supernumerary or missing teeth were included. The exclusion criteria were patients with systemic diseases, past or present use of medications that influence gingival enlargement, pregnancy, lactation, menstruation, gingival enlargements, gingival recession, history of orthodontic treatment, diastema, no proximal contact in the maxillary anterior teeth (including the first maxillary premolar), attrition scores >1 [22], or anomalies in maxillary anterior teeth.

Signs of periodontitis or gingivitis, as well as the presence of any calculus in the anterior maxillary region, were grounds for exclusion, along with patients exhibiting a bleeding on probing rate exceeding 10% [23]. During the initial appointment, the plaque index according to Silness and Löe [24], the gingival index as per Löe and Silness [25], and probing depths from 6 points on all teeth were recorded using a 0-3 scoring system and a periodontal chart. Probing procedures were conducted with mild pressure (approximately 0.5 N) using a periodontal probe (Hu-Friedy, Chicago, IL, USA) with a 0.5-mm diameter. The gingival and plaque indexes for all teeth were documented as percentages. Only individuals with plaque and gingival index scores of 0% and probing depths less than 3 mm [18] were included in the study. All participants received oral hygiene instructions, and if necessary, scaling and polishing procedures were performed. Following the indexing procedures, the study parameters were measured.

Intraoral scanning procedures

To mark the mucogingival line, histochemical staining was employed. The anterior portion of the maxillary gingiva, extending to the premolar region, was stained with a 5% iodine Lugol's solution using a cotton pellet and light-pressure brushing. The solution was applied multiple times until a distinct demarcation line was achieved. The mechanism of histochemical staining relies on iodine-positive staining of alveolar mucosa with high glycogen content, while iodine-negative staining occurs in keratinized gingiva with low glycogen content. Once the distinct line was obtained, a soft tissue retractor (Optragate, Ivoclar Vivadent®, Schaan, Liechtenstein) was positioned to facilitate scanning and to minimize the movement of the oral mucosa, thereby reducing the uncertainty of the demarcation line due to the patient's lip movement. An IOS (CEREC Omnicam, Dentsply Sirona, Bensheim, Germany) was used for scanning. All scans were performed in a similar manner, starting with the occlusal and oral side of the right first premolar and extending to the buccal side, then continuing with the left side using a similar approach and returning to the right quadrant [1]. It was ensured that all scans included the deepest part of the vestibule, a clear demarcation of the mucogingival junction, and the incisal edge of the teeth in the maxillary anterior region (including first premolars). Scanning was carried out with a 20.0 mm scanning depth, as per the manufacturer's instructions.

Transgingival probing procedures

The facial GT of central, lateral, and canine teeth was measured using the transgingival sounding method with an endodontic finger spreader (ISO #30) (Dentsply Maillefer, Ballaigues, Switzerland) equipped with a silicone stopper that lacked a pre-existing hole for stabilization. Prior to measurements, a topical anesthetic containing 10% lidocaine (Xylocaine spray, AstraZeneca, Osaka, Japan) was applied. Local anesthetic was not used to avoid altering gingival volume [26]. Measurements were taken at the marked point located at the buccal midline projection of the crown and 1 mm apical to the gingival margin [3]. The endodontic spreader was inserted perpendicularly into the gingiva until it reached the hard tissue of the tooth. The spreader's insertion was stabilized using a flowable composite (Clearfil Majesty ES Flow, Kuraray Noritake Dental, Tokyo, Japan) and polymerized with a light curing unit (Elipar DeepCure-S, 3M ESPE, Seefeld, Germany). After securing the stopper's position, the spreader was removed. All GT assessments were conducted by 2 observers (AMN, a periodontist with 10 years of experience, and DY, an endodontist with 5 years of experience). Before the assessment process, the observers were calibrated by measuring the GT thicknesses of all maxillary anterior teeth in 6 patients (10% of the total sample size) using the spreader, and photographs of the spreaders were taken. Measurements were performed on the photographs (explained below), and Cohen's kappa scores were obtained (ranging from 0.88 to 0.94). For inter-observer reliability, both observers examined all maxillary anterior teeth using the exact same procedures.

GT: Each insertion depth of the spreader was photographed alongside an endodontic ruler (Dentsply Sirona, Ballaigues, Switzerland). A total of 360 photographs, representing 360 teeth from 60 patients, were compiled into a dataset. To account for inter-observer reliability, 2 datasets (720 photos) were created for 2 observers. The first dataset was designated for the measurements of the first observer (AMN), while the second dataset was assigned to the second observer (DY). An independent observer randomly coded the photos in both datasets. To calibrate the observers, measurements were performed on 36 photos (10% of the total sample size), and Cohen's kappa values were obtained (ranging from 0.97 to 0.98). Two investigators (AMN and DY), blinded to the data of teeth and patients, conducted the GT measurements in the photos using image software (Image J, National Institutes of Health, Bethesda, MD, USA) twice, with a 2-week interval between measurements. Ten photos were measured at a time, with breaks taken after every ten measurements to eliminate eye fatigue for the observers. For the first and second datasets, inter-class and intra-class correlations (ICCs) were obtained by the 2 observers on 2 separate occasions.

For the measurements of KGW, PH, and CR, the software of an IOS (CEREC Omnicam, software version 4.6.1, Dentsply Sirona) was utilized. All measurements were conducted on 3-dimensional reconstructions. During the measurement process, each tooth was positioned at the center of the screen, ensuring that its mesial and distal edges, as well as the entire buccal surface, were visible **(ure 1)**. Two investigators (AMN and DY), who were calibrated by examining the data of 6 individuals (10% of the total sample size), carried out the measurements, and Cohen's kappa scores were reported (ranging from 0.94 to 0.97). One observer measured all samples 3 times, and the mean values were recorded for statistical analysis. The measurements were recorded in millimeters.

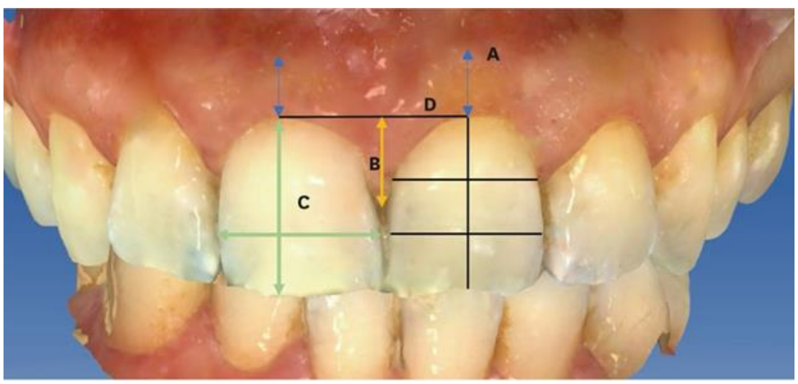

Figure 1 Measurements of keratinized gingiva width (A), papilla height (B), crown length, and width (C) for central teeth. The line between the zenith points of 2 adjacent teeth (D).

KGW: The gingival zenith positions of the teeth adjacent to the papilla were identified, and a zenith line was drawn connecting these points [5]. KGW measurements were taken perpendicularly from this zenith line to the midline projection of the tooth crown. The distance between the mucogingival junction and the gingival margin was then recorded.

PH: To measure the PH, the distance between the zenith line and the tip of the papilla was assessed parallel to the long axis of the crown.

CR: Both crown length and crown width were measured. To determine the crown length, the distance between the gingival zenith point and the incisal edge of the tooth was measured perpendicularly to the zenith line. In order to measure the crown width, the crown length was divided into 3 equal sections: coronal, middle, and incisal. The width of the crown was then measured at the border between the coronal and middle sections, parallel to the zenith line [6]. The CR was calculated by dividing the width by the length of the crown.

Data were collected for assessments of the intra- and inter-observer reliability of the PH, CR, and KGW parameters by having 2 observers measure all data twice.

Statistical analysis

Statistical analysis was performed using SPSS software version 26.0 (IBM Corp., Armonk, NY, USA). The normality of the distribution was assessed using the Kolmogorov-Smirnov test. As a normal distribution was not obtained, the relationships between the data for GT, KGW, PH, and CR were analyzed using the Spearman correlation test. To statistically analyze GT and KGW between groups of teeth, 1-way analysis of variance (ANOVA) was employed. The Student's *t*-test was utilized to compare the study parameters based on sex. The level of statistical significance was set at $P<0.05$, with a 95% confidence interval. ICCs were used to assess intra- and inter-observer reliability. For the ICC, the level of statistical significance was set at $P<0.001$.

Results and Discussion

Initially, 81 individuals were evaluated for the study; however, only 60 individuals met the inclusion criteria. A total of 360 maxillary anterior teeth were assessed. Following the clinical procedures, no adverse operative or postoperative complications were observed, such as dilaceration, hemorrhage, infection, or petechiae on soft tissue during the 2-day observation period. The mean and standard deviation values for GT, KGW, PH, and CR in the maxillary anterior region are presented in **Table 1**. Based on 1-way ANOVA, no statistically significant differences were observed among teeth in terms of GT ($P=0.06$). However, a statistically significant difference was found between central incisors and canines for KGW ($P=0.007$), as well as between canines and lateral incisors for PH ($P=0.047$). The CR values were highest in central incisors and lowest in lateral incisors ($P<0.001$). No statistically significant differences were detected between male and female participants for any of the study parameters ($P>0.05$).

Table 1. Values of GT, KGW, PH, and CR in central, lateral, and canine teeth (in mm)

Variables	Central (n=120)	Lateral (n=120)	Canine (n=120)	*P* value
GT	1.01±0.02	1.00±0.02	0.96±0.02	0.06
KGW	4.80±0.13[a)]	4.67±0.12	4.23±0.13[a)]	0.007[a)]
PH	3.20±0.11	2.99±0.06[a)]	3.24±0.07[a)]	0.047[a)]
CR	0.88±0.01[a)]	0.79±0.01[a)]	0.80±0.01[a)]	<0.001[a)]

Values are presented as mean ± standard deviation.
GT: gingival thickness, KGW: keratinized gingiva width, PH: papilla height, CR: crown ratio.
[a)]Denotes statistical significance according to 1-way analysis of variance ($P<0.05$).

Table 2 and **Figure 2** display the correlations among the study parameters. Spearman correlation coefficient analysis revealed a moderate negative correlation between GT and KGW in the central region ($P=0.019$). Additionally, a moderate negative correlation was observed between KGW and PH in the central region ($P=0.01$). Regarding the relationship between KGW and CR, a weak negative correlation was identified in the central region ($P=0.043$). No statistically significant differences were found in the canine and lateral regions for GT, KGW, PH, and CR ($P>0.05$).

Table 2. Correlations between GT, KGW, PH, and CR in central, lateral, and canine teeth

Variables	GT (r-value)			KGW (r-value)			PH (r-value)		
	Central	Lateral	Canine	Central	Lateral	Canine	Central	Lateral	Canine
CR	0.107	−0.053	0.201	−0.264[b)]	−0.119	−0.088	0.083	−0.001	−0.040
PH	0.085	0.019	−0.193	−0.333[c)]	0.085	−0.024	1.000	1.000	1.000
KGW	−0.305[a)]	−0.158	−0.071	1.000	1.000	1.000	−0.333[c)]	−0.085	−0.024

GT: gingival thickness, KGW: keratinized gingiva width, PH: papilla height, CR: crown ratio.
Superscript lowercase letters denote statistical significance according to the Spearman correlation test ([a)]$P=0.019$, [b)]$P=0.043$, [c)]$P=0.010$).

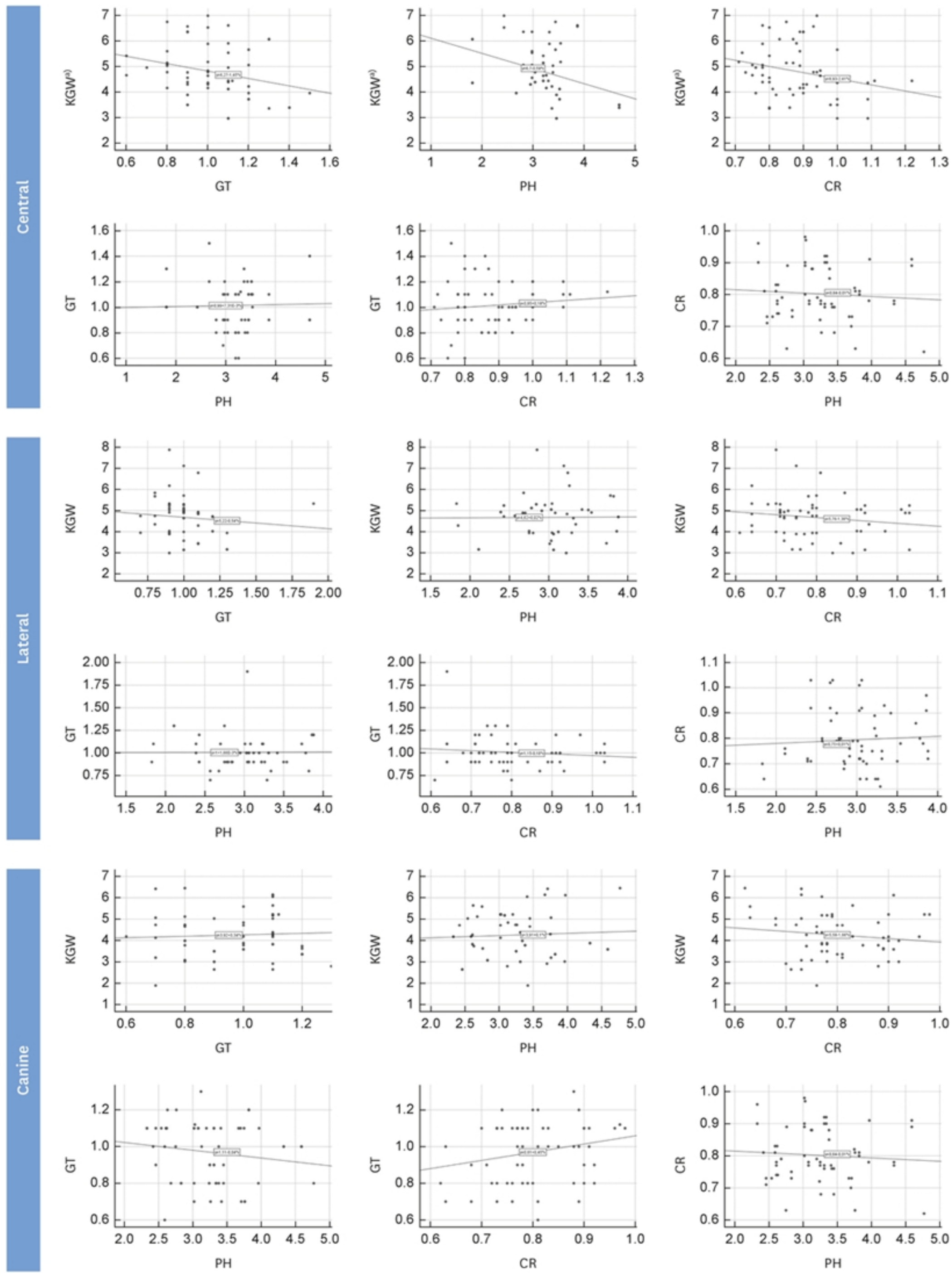

Figure 2 . Simple scatter plots of the correlations between GT, KGW, PH, and CR belonging to central, lateral, and canine teeth.

GT: gingival thickness, KGW: keratinized gingiva width, PH: papilla height, CR: crown ratio.
[a)]Statistically significant difference according to the Spearman correlation test (*P*<0.05).

In the first dataset, the ICCs for the GT measurements were 0.974 and 0.982, respectively. For the second dataset, the ICCs were 0.979 and 0.991, respectively. No statistically significant differences were observed between the measurements of the first and second datasets (P>0.001). Likewise, no significant differences were found between the intra- and inter-observer measurement values for the KGW, PH, and CR (P>0.001).

The primary finding of this study was a weak negative correlation between GT and KGW, as well as between KGW and PH, and between KGW and CR in the central incisors. In the lateral incisors and canine, no significant correlation was observed among all variables. Additionally, for all maxillary anterior teeth, no correlation was found between other parameters. Consequently, our first null hypothesis was partially rejected.

The periodontal phenotype has a direct impact on the healing process following periodontal treatments; therefore, more accurate methods are required, as opposed to subjective approaches that yield conflicting results [23, 27]. The second null hypothesis was also partially rejected. No difference was observed in the maxillary anterior teeth regarding GT; however, differences were found in KGW, PH, and CR.

In our study, GT values ranged from 0.96 to 1.01 mm. Our findings were consistent with previous studies that reported GT values between 0.81 and 1.23 mm [28, 29]. It is important to note that achieving complete root coverage is associated with a minimum thickness of 1.1 mm [30]. Based on our study results, maxillary anterior teeth are more susceptible to requiring second-step periodontal plastic surgery during the root coverage process. GT has been considered as either site-specific or patient-specific determinants [11]. However, our study did not find any differences in GT among the maxillary anterior teeth. Previous studies have reported that the thinnest gingiva was found in canines among the maxillary anterior teeth [16, 17]. There are conflicting results regarding the influence of sex on gingival phenotype [16, 23, 31, 32]. In our study, we observed no differences between female and male participants, which is in line with some previous studies [16, 23] but contradicts others [31, 32].

We measured the GT using an endodontic spreader. In the literature, various instruments have been used to analyze the GT, including an endodontic file [21], spreader [14], acupuncture needle [7], and periodontal probe [7, 11, 16]. The endodontic spreader offers suitable tip and body properties for accurate, error-free measurement. Unlike an endodontic file with blades that can cause micro-retention and friction, the spreader easily penetrates soft tissue, yielding more precise results on a micro-scale.

The GT values were analyzed in millimeters in this study, rather than relying on categorical classifications (e.g., thin or thick biotype). This approach allowed for more comprehensive results, as it enabled the detection of extremely thin or thick gingival profiles. One limitation of classifying gingiva as either a thick or thin biotype, rather than using quantitative analysis, is that the 1-mm threshold has been questioned in terms of its accuracy for diagnosis and prognosis [3]. Therefore, presenting the research findings as numerical data, rather than simplifying them into a single descriptor (i.e., thin or thick), offers a more valid interpretation of previous studies in the event of a potential paradigm shift regarding the clinical threshold through future research. The most significant drawbacks of the transgingival probing method include its invasiveness and its low sensitivity when dealing with very thin tissues [21].

The use of non-invasive IOS has been explored for analyzing gingival tissues in periodontology [8, 15, 33]. Furthermore, IOS is not only utilized for digital measurements of gingival tissues, but also for tracking morphological changes in the gingiva following initial periodontal therapy [34]. Our study presents a comparison of GT with KGW obtained using IOS, which has previously demonstrated its reliability in periodontal measurements [7]. The clinical significance of our study lies in comparing the KGW values acquired through an easy and non-invasive method, which is more reliable than probing for KGW [15], with GT.

Our study results indicate that the maxillary anterior teeth did not exhibit a KGW of less than 2 mm, which is consistent with the findings in the literature [11, 16, 21, 33, 35, 36]. We observed a narrower KGW in canines than in central incisors. However, the literature presents inconsistent results, such as a higher KGW in central incisors [35], a higher KGW in canines [13, 31, 35], or no significant difference between the 2 groups of teeth [17, 19, 21].

Determining the mucogingival junction is a crucial parameter for accurately measuring KGW. The mucogingival junction is defined as the boundary between movable and immovable mucosa. According to the literature, no significant differences were found among the 3 methods for determining the junction: the visual method (identifying a scalloped line), the functional method (assessing tissue mobility by sliding a horizontally positioned periodontal probe from the vestibule towards the gingival margin using light pressure), and histochemical staining (staining with an iodine solution) [37]. Furthermore, a recent study employed a software program that removes oral mucosa to determine the mucogingival line [20]. In our study, we used histochemical staining to identify the mucogingival line.

Relationship between KGW and GT: Generally, the KGW is measured using a periodontal probe due to its simplicity [11, 16, 19]. However, a previous study reported that measurements taken with a periodontal probe can overestimate the KGW by approximately 1 mm compared to the actual value [15]. Therefore, we utilized an IOS to measure the KGW and compared it with the GT, revealing a negative correlation between the GT and the KGW in the central region, meaning that a thinner GT was associated with a wider KGW.

In the literature, most studies have reported a positive correlation between these 2 parameters [11, 13, 16, 17, 19, 21, 36], although several studies have reported no correlation [6, 38]. This discrepancy may be attributed to differences in methodologies and racial factors. It is important to note that the periodontal probe tends to overestimate the KGW by approximately 1 mm [15]. Unfortunately, most studies in the literature that compared GT and KGW measured this distance using periodontal probes [11, 13, 16, 17, 19, 21, 36]. Therefore, we suggest that these data need to be re-evaluated. Similarly, a recent review highlighted the heterogeneous methodologies of studies investigating the correlation between GT and KGW [4]. Additionally, in the literature, KGW has been analyzed using high-resolution clinical photographs [20]. Further clinical studies are necessary to better understand the differences between digital measurements. Based on our findings, when a wider KGW is present, clinicians should exercise greater diligence in treatment planning or comprehensive examination with regard to GT, particularly in the central region.

From the perspective of invasiveness, measuring KGW using IOS is non-invasive, but our method for analyzing GT was invasive. In the literature, GT has been examined through the superimposition of cone-beam computed tomography (CBCT) images and intraoral scans, yielding results comparable to direct measurements using an endodontic spreader [39]. Given the concern for radiation exposure, this non-invasive approach may be valuable for patients who already have CBCT images available.

In our study, the PH values ranged from 2.99 to 3.24 mm, with the lateral incisor having a lower PH than the canine. In the literature, some studies utilized a reference line extending between the zenith points of 2 adjacent teeth for the papilla base [6, 12, 23, 27, 40], while others employed a line corresponding to the gingival zenith point and perpendicular to the tooth's long axis [13, 41-43]. Regarding the numerical data, the PH values of the maxillary anterior teeth were found to be between 3.26 and 5.16 mm [5, 6, 11-13, 23, 27, 36, 38, 40-43]. Our result of 2.99 mm for PH is the lowest reported in healthy subjects to date. In prior studies, the PH was measured using either a periodontal probe [5, 11, 36, 38, 41] or a digital caliper on a cast model [6, 12, 13, 23, 43]. Both methods involve measuring a curved surface, the interdental papilla, with an instrument designed to measure a line, or a 2-dimensional space. However, there is no explanation provided for the angle on the third dimension, which is difficult to standardize. Consequently, the repeatability of the measurement may be questionable. Similar to the measurement of KGW [15], using a periodontal probe may have led to an overestimation of the PH values. Nevertheless, it is important to note that the reliability of the measurement would improve with the use of a jig that standardizes the measurement position and stabilizes the angle of the probe. Yin *et al*. [27] measured the PH using a scan obtained from the cast model. However, the accuracy of the impression and modeling procedures may affect the actual size of the papilla, which is a soft and labile tissue, leading to changes on the scale of millimeters. In our study, we scanned the papilla and directly measured it on this scan. These methodological nuances account for the differences in the results.

Relationship between PH and GT: Our study revealed no correlation between PH and GT in the maxillary anterior region. The literature presents inconsistent findings; some studies reported no correlation [36], while others suggested a higher papilla is related to thick gingiva [11] and thin gingiva [41, 43]. Those studies examined the relationship between GT and PH using qualitative rather than quantitative methods [11, 41, 43]. In contrast, our study employed numerical data to investigate this relationship.

Relationship between PH and KGW: We discovered a moderate negative correlation between KGW and PH. Although no significant correlation has been previously demonstrated [11], that study measured KGW using a periodontal probe and did not report any numerical data. Our research quantitatively compared PH and KGW, revealing a wider KGW associated with lower PH. To better comprehend the direct relationship, further studies employing reliable and precise methods are necessary.

In our study, the CR in the central region was larger than in the canine and lateral regions. This finding is consistent with previous studies [12, 23]. In the literature, various methods have been used to analyze the relationship between CR and different parameters, such as measuring the width of the crown at the middle and apical thirds [6, 12, 13, 40] or at the incisal third [12, 23]. Although these ratios are primarily deterministic, the width at the apical region is related to the tooth's emergence profile, while the width at the incisal region is related to the contact form. A previous study suggested that cervical width provides more objective results for CR. However, when the crown length is divided into 3 portions, both cervical and incisal widths can yield similarly objective results.

Relationship between CR and GT: We discovered no correlation between CR and GT. In agreement with our findings, some studies also reported no correlation [13, 35]. However, in contrast to our results, other studies identified a positive correlation [22, 36, 40].

Relationship between CR and KGW: Our study's results revealed no correlation between CR and KGW. The existing literature contains limited data on this topic, with only a few studies examining the relationship between attached gingiva and crown length, yielding conflicting results [13, 31, 40]. Authors who reported a positive correlation attributed it to the impact of attrition or gingival recession [13]. However, this study excluded cases with incisal edge attrition and gingival recession.

Relationship between CR and PH: The present study found no correlation between CR and PH. Many studies have reported a relationship between papilla shape and crown form [6, 12, 13, 23, 40]. Generally, a longer crown is associated with a decreased CR and a longer papilla, resulting in an increased PH [12, 13, 23]. This discrepancy may be due to differences in methodology and study populations. Reduced crown length resulting from attrition could have influenced the outcomes of research, especially in older populations. In terms of crown shape, it has been suggested that a square crown form has a longer contact point and a shorter papilla [6, 12, 23]. However, our study did not find a relationship between these 2 parameters. In the literature, a periodontal probe was used to measure PH and CR parameters [6], providing moderately accurate dimensions, rounded to the nearest 0.5 mm. Another group of studies employed digital calipers to measure parameters on cast models [5, 12, 23]. In contrast, our study utilized scanned data and a digital tool to measure exact distances with high accuracy, ensuring that reference points were repeatable and precise. Stellini *et al*. [40] used photographs with a ruler as a guide for digitally measuring parameters and reported a relationship between crown form and PH. In our study, we used IOS data for digital measurements. Further research is needed to compare the accuracy of various digital methods.

The limitations of this study are the exclusion of various age groups and reliance on a single brand of IOS. Furthermore, the results are specific to maxillary anterior teeth and the native Turkish population. It is important to note that our mean values provide a benchmark result. In clinical practice, evaluations should be conducted on a case-by-case basis. The strength of this study lies in the use of an IOS, a user-friendly and reproducible method for measuring KGW in comparison to various parameters, including GT. The key takeaways from this study are the negative correlation between GT and KGW obtained using an IOS, which is a more accurate method than the periodontal probe, and the need for further research to compare the reliability of IOS with other methods.

Conclusion

In conclusion, the major results are as follows:

- There was a moderate negative correlation between KGW and GT in the central region when KGW was obtained using an IOS.
- The widely proposed hypothesis, according to which there is a positive correlation between GT and KGW, may be met with skepticism.
- A moderate negative correlation existed between PH and KGW in the central region.
- A weak negative correlation was detected between CR and KGW in the central region.
- PH was lower in lateral teeth than in canines, while KGW was lower in canines than in central teeth.

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References

1. Wei D, Di P, Tian J, Zhao Y, Lin Y. Evaluation of intraoral digital impressions for obtaining gingival contour in the esthetic zone: accuracy outcomes. Clin Oral Investig. 2020;24(4):1401–10.
2. Jepsen S, Caton JG, Albandar JM, Bissada NF, Bouchard P, Cortellini P, 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 Clin Periodontol. 2018;45(Suppl 20):S219–29.
3. Frost NA, Mealey BL, Jones AA, Huynh-Ba G. Periodontal biotype: gingival thickness as it relates to probe visibility and buccal plate thickness. J Periodontol. 2015;86(8):1141–9.
4. Vlachodimou E, Fragkioudakis I, Vouros I. Is there an association between the gingival phenotype and the width of keratinized gingiva? A systematic review. Dent J (Basel). 2021;9(4):34.
5. Chu SJ, Tan JH, Stappert CF, Tarnow DP. Gingival zenith positions and levels of the maxillary anterior dentition. J Esthet Restor Dent. 2009;21(2):113–20.
6. 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(7):865–9.
7. Kloukos D, Koukos G, Doulis I, Sculean A, Stavropoulos A, Katsaros C, et al. Gingival thickness assessment at the mandibular incisors with four methods: A cross-sectional study. J Periodontol. 2018;89(10):1300–9.
8. Kloukos D, Koukos G, Gkantidis N, Sculean A, Katsaros C, Stavropoulos A. Transgingival probing: A clinical gold standard for assessing gingival thickness. Quintessence Int. 2021;52(5):394–401.
9. Kan JY, Morimoto 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(3):237–43.
10. Lin GH, Chan HL, Wang HL. The significance of keratinized mucosa on implant health: A systematic review. J Periodontol. 2013;84(12):1755–67.
11. De Rouck T, Eghbali R, Collys K, De Bruyn H, Cosyn J. 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(10):428–33.
12. Song JW, Leesungbok R, Park SJ, Chang SH, Ahn SJ, Lee SW. Analysis of crown size and morphology, and gingival shape in the maxillary anterior dentition in Korean young adults. J Adv Prosthodont. 2017;9(4):315–20.
13. 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(8):570–7.
14. Gánti B, Bednarz W, Kőműves K, Vág J. Reproducibility of the PIROP ultrasonic biometer for gingival thickness measurements. J Esthet Restor Dent. 2019;31(3):263–7.
15. Lee JS, Jeon YS, Strauss FJ, Jung HI, Gruber R. Digital scanning is more accurate than using a periodontal probe to measure the keratinized tissue width. Sci Rep. 2020;10:3665.
16. Egreja AM, Kahn S, Barceleiro M, Bittencourt S. Relationship between the width of the zone of keratinized tissue and thickness of gingival tissue in the anterior maxilla. Int J Periodont Restor Dent. 2012;32(5):573–9.
17. Shah R, Sowmya NK, Mehta DS. Prevalence of gingival biotype and its relationship to clinical parameters. Contemp Clin Dent. 2015;6(Suppl 1):S167–71.
18. Fischer KR, Grill E, Jockel-Schneider Y, Bechtold M, Schlagenhauf U, Fickl S. On the relationship between gingival biotypes and supracrestal gingival height, crown form and papilla height. Clin Oral Implants Res. 2014;25(7):894–8.
19. Jing WD, Xu L, Xu X, Hou JX, Li XT. Association between periodontal biotype and clinical parameters: A cross-sectional study in patients with skeletal class III malocclusion. Chin J Dent Res. 2019;22(1):9–19.

20. Ko KA, Lee JS, Kim JH, Park JM, Gruber R, Thoma DS. Changes in mucogingival junction after an apically positioned flap with collagen matrix at sites with or without previous guided bone regeneration: A prospective comparative cohort study. Clin Oral Implants Res. 2020;31(11):1199–206.
21. 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.
22. Smith BG, Knight JK. An index for measuring the wear of teeth. Br Dent J. 1984;156(12):435–8.
23. Zhong C, Yingzi X, Zhiqiang L, Peishuang W, Yimin Z, Shanqing G, et al. Analysis of crown morphology and gingival shape in the maxillary anterior dentition. Int J Periodont Restor Dent. 2020;40(6):925–31.
24. Silness J, Löe H. Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition. Acta Odontol Scand. 1964;22(1):121–35.
25. Löe H, Silness J. Periodontal disease in pregnancy. I. Prevalence and severity. Acta Odontol Scand. 1963;21(6):533–51.
26. 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(3):146–56.
27. Yin XJ, Wei BY, Ke XP, Zhang T, Jiang MY, Luo XY, et al. Correlation between clinical parameters of crown and gingival morphology of anterior teeth and periodontal biotypes. BMC Oral Health. 2020;20:59.
28. Kim YJ, Park JM, Kim S, Koo KT, Seol YJ, Lee YM, et al. New method of assessing the relationship between buccal bone thickness and gingival thickness. J Periodontal Implant Sci. 2016;46(6):372–81.
29. La Rocca AP, Alemany AS, Levi PJ Jr, Juan MV, Molina JN, Weisgold AS. Anterior maxillary and mandibular biotype: relationship between gingival thickness and width with respect to underlying bone thickness. Implant Dent. 2012;21(6):507–15.
30. Hwang D, Wang HL. Flap thickness as a predictor of root coverage: A systematic review. J Periodontol. 2006;77(10):1625–34.
31. Jennes ME, Sachse C, Flügge T, Preissner S, Heiland M, Nahles S, et al. Gender- and age-related differences in the width of attached gingiva and clinical crown length in anterior teeth. BMC Oral Health. 2021;21:287.
32. Vandana KL, Savitha B. Thickness of gingiva in association with age, gender and dental arch location. J Clin Periodontol. 2005;32(8):828–30.
33. Lim HC, Lee J, Kang DY, Cho IW, Shin HS, Park JC. Digital assessment of gingival dimensions of healthy periodontium. J Clin Med. 2021;10(8):1550.
34. Zhang J, Huang Z, Cai Y, Luan Q. Digital assessment of gingiva morphological changes and related factors after initial periodontal therapy. J Oral Sci. 2021;63(1):59–64.
35. 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(10):839–45.
36. 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(12):1132–9.
37. Guglielmoni P, Promsudthi A, Tatakis DN, Trombelli L. Intra- and inter-examiner reproducibility in keratinized tissue width assessment with three methods for mucogingival junction determination. J Periodontol. 2001;72(1):134–9.
38. Joshi A, Suragimath G, Zope SA, Ashwinirani SR, Varma SA. Comparison of gingival biotype between different genders based on measurement of dentopapillary complex. J Clin Diagn Res. 2017;11(7):ZC40–ZC45.
39. Couso-Queiruga E, Tattan M, Ahmad U, Barwacz C, Gonzalez-Martin O, Avila-Ortiz G, et al. Assessment of gingival thickness using digital file superimposition versus direct clinical measurements. Clin Oral Investig. 2021;25(7):2353–61.
40. Stellini E, Comuzzi L, Mazzocco F, Parente N, Gobbato L. Relationships between different tooth shapes and patient's periodontal phenotype. J Periodontal Res. 2013;48(5):657–62.
41. Chow YC, Eber RM, Tsao YP, Shotwell JL, Wang HL. Factors associated with the appearance of gingival papillae. J Clin Periodontol. 2010;37(8):719–27.
42. Kolte AP, Kolte RA, Pajnigara NG. A clinical and radiographic assessment of positional variations of gingival papilla and its proportions. Int J Periodont Restor Dent. 2016;36(2):213–8.

43. Lee SP, Kim TI, Kim HK, Shon WJ, Park YS. Discriminant analysis for the thin periodontal biotype based on data acquired from three-dimensional virtual models of Korean young adults. J Periodontol. 2013;84(11):1638–45.