Original Article

EVALUATION OF PERI-IMPLANT CLINICAL AND RADIOGRAPHIC PARAMETERS IN RELATION TO KERATINIZED MUCOSA WIDTH

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Received: 23 May 2025; **Revised:** 11 August 2025; **Accepted:** 12 August 2025 https://doi.org/10.51847/kJd4UlHxDj

ABSTRACT

The long-term success of dental implants relies not only on osseointegration but also on the preservation of peri-implant soft and hard tissue health. Among several influencing factors, the width of keratinized mucosa (WKM) has garnered significant interest due to its potential role in maintaining peri-implant tissue stability. This study aimed to evaluate the association between the width of keratinized mucosa and peri-implant clinical and radiographic parameters in systemically healthy individuals. Between May and September 2024, a cross-sectional study was conducted at the Department of Implantology, Saveetha Dental College and Hospitals, Chennai. A total of 357 systemically healthy, non-smoking individuals aged 25–60 years with a single implant in function for at least 12 months were included. Clinical parameters including plaque index (PI), gingival index (GI), peri-implant probing depth (PPD), clinical attachment level (CAL), mucosal recession (MR), and WKM were recorded. Crestal bone level (CBL) was assessed radiographically. Based on WKM, implants were categorized into adequate (≥2 mm) and inadequate (<2 mm) groups. Statistical analysis was performed using the independent t-test with a significance threshold of $p < 0.05$. Implants with inadequate WKM exhibited significantly higher PI, GI, PPD, CAL, MR, and CBL compared to those with adequate WKM ($p < 0.05$), indicating poorer peri-implant tissue health.An inadequate width of keratinized mucosa was associated with unfavourable peri-implant clinical and radiographic outcomes. This highlights the importance of assessing and preserving adequate WKM around implants to enhance long-term success.

Key words: Dental implants, Keratinized mucosa, Peri-implant diseases, Peri-implant health.

Introduction

Dental implants, which provide both practical and aesthetic advantages, are now a commonly used and reliable method of replacing lost teeth [1-3]. The peri-implant tissue has to be maintained in good condition for dental implants to function throughout time. An implant's initial stability is guaranteed by osseointegration, but maintaining the soft and hard tissues around it is essential to ensuring its durability and continuous functionality [4]. Peri-implant health is influenced by several factors, which may be roughly divided into variables relating to the patient and the implant.

Systemic diseases such as osteoporosis, diabetes mellitus, and immunosuppression are patient-related variables that might impair the host immune response and increase the patient's susceptibility to inflammation around the implant and bone loss. Habits like smoking and inadequate oral hygiene are well-established risk factors that promote microbial colonization and impair soft tissue healing [5, 6]. Furthermore, because periodontal and peri implant lesions overlap microbial profiles and host responses, an elevated incidence of peri-implantitis has been substantially linked to a history of periodontal disease [7-9].

Implant-related factors involve the design and surface characteristics of the implant, which influence osseointegration and bacterial adherence. Prosthetic factors such as over-contoured crowns or suboptimal emergence profiles may hinder plaque control and disrupt soft tissue stability [10-13]. Moreover, bone quality and quantity at the implant site, the surgical technique employed, and the timing and magnitude of prosthesis loading all play crucial roles in maintaining peri-implant tissue integrity by affecting stress distribution, mucosal sealing, and microbial dynamics [14-18].

Among these factors, there has been growing interest in the function of peri-implant soft tissue properties, namely the width of keratinized mucosa (WKM). Keratinized mucosa is believed to contribute to better plaque control, reduced mucosal inflammation, greater resistance to mechanical trauma, and improved patient comfort [19]. While some clinical studies affirm the necessity of an adequate WKM (typically ≥2 mm) to prevent peri-implant soft tissue complications [20, 21] Others contend that implant success may be attained even in the absence of plaque if it is well controlled [22, 23].

The current cross-sectional study was carried out in light of this disagreement with the aim of assessing the relationship between keratinized mucosa width and peri-implant radiographic and clinical characteristics in people in excellent general health [24, 25]. The study aims to elucidate

the impact of WKM on peri-implant health by comparing the results of implants with appropriate and inadequate WKM.

Materials and Methods

Upon receiving ethical clearance from the Institutional Review Board, this cross-sectional investigation was undertaken in the Department of Implantology at Saveetha Dental College and Hospitals, Chennai, over the period of May to September 2024. All subjects gave their informed permission before being enrolled, and the study closely followed the guidelines set forth in the Declaration of Helsinki.

The study population comprised systemically healthy, non-smoking individuals between 25 and 60 years of age, each of them was presenting with a single dental implant that had been fixed and operational for a minimum of a year [26-29]. To eliminate confounding influences, only patients with no history of periodontal disease, systemic illness, antibiotic or anti-inflammatory usage within the preceding six months, or previous soft or hard tissue augmentation at the implant site were considered eligible. Participants were also required to have demonstrated consistent compliance with a 6-monthly professional maintenance schedule. Only one implant per subject was selected to ensure independent observations, and implants adjacent to other implants or edentulous spaces were excluded.

A single calibrated examiner (KK) conducted all clinical assessments in order to maintain uniformity and reduce inter-examiner variability. Plaque index (PI), gingival index (GI), peri-implant probing depth (PPD), clinical attachment level (CAL), mucosal recession (MR), and width of keratinized mucosa (WKM) were among the characteristics assessed. The Silness and Löe index was used to assess PI. Scores were taken from the buccal, lingual, distal, and mesial areas around each implant, and the average score was utilized for analysis. Similarly, the gingival index (GI) was assessed according to the criteria proposed by Löe and Silness. A calibrated periodontal probe (Hu-Friedy®, Chicago, USA) was used to measure the peri-implant probing depth (PPD) and clinical attachment level (CAL) at six different implant sites: mesio-buccal, mid-buccal, disto-buccal, mesio-lingual/palatal, mid-lingual/palatal, and disto-lingual/palatal. For statistical comparison, the average of these six measurements was determined. At each location, MR was measured as the vertical distance between the mucosal margin and the implant prosthesis margin. The distance between the mucogingival junction and the free mucosal margin was used to calculate WKM at the mid-buccal aspect. Implants were divided into two groups according to the WKM measurement: those with keratinized mucosa widths ≥2 mm and those with <2 mm.

Digital periapical radiographs that were standardized and acquired by the paralleling approach were used for radiographic assessment. On both the mesial and distal sides of each implant, the line extending from the implant platform to the greatest coronal point of bone-implant contact was measured in order to determine the crestal bone level (CBL). To determine each implant's overall crestal bone condition, the mean of these two values was computed.

Assuming a modest effect size, an alpha error of 0.05, and a power of 90%, the G*Power program (Version 3.1.9.4) was used to estimate the sample size and found that a minimum of 300 implants were needed to attain statistical validity.

Statistical analysis

The data was compiled and analyzed using IBM SPSS Statistics software (Version 23.0; IBM Corp., Armonk, NY, USA). Continuous variables such as PI, GI, PPD, CAL, MR, and WKM were assessed for normality using the Shapiro–Wilk test. As all variables followed a normal distribution, intergroup comparisons between the adequate and inadequate WKM groups were performed using the independent samples t-test. A p-value of less than 0.05 was considered statistically significant for all comparisons.

Results and Discussion

Out of the 357 implants that were examined, 285 (79.8%) had keratinized mucosa that was sufficiently wide (≥2 mm), whereas 72 implants (20.2%) had keratinized mucosa that was too narrow. The study population was 44.62 ± 7.31 years old on average, and there were 190 females (53.2%) and 167 men (46.8%).

The insufficient WKM group had substantially higher mean PI (1.18 ± 0.34 vs. 0.62 ± 0.21; $p < 0.05$), GI (1.09 ± 0.29 vs. 0.58 ± 0.19; $p < 0.05$), PPD (4.12 ± 0.57 mm vs. 3.21 ± 0.46 mm; $p < 0.05$), and CAL (4.38 ± 0.61 mm vs. 3.34 ± 0.52 mm; $p < 0.05$) in the inadequate WKM group. Furthermore, the group with inadequate WKM showed significantly greater MR (1.02 ± 0.47 mm vs. 0.39 ± 0.28 mm; $p < 0.05$). The measured WKM of the appropriate WKM group was significantly greater (3.12 ± 0.42 mm vs. 1.16 ± 0.38 mm; $p < 0.05$), as expected. Furthermore, the insufficient WKM group's CBL was considerably more apical (2.03 ± 0.41 mm) than the adequate group's (1.28 ± 0.35 mm; $p < 0.05$), suggesting a higher loss of bone **(Table 1)**.

Table 1. Group-wise Comparison Based on Width of Keratinized Mucosa

Outcome Parameters	Adequate WKM (n = 285) Mean ± SD	Inadequate WKM (n = 72) Mean ± SD	p-value
PI	0.62 ± 0.21	1.18 ± 0.34	0.00*
GI	0.58 ± 0.19	1.09 ± 0.29	0.00*
PPD (mm)	3.21 ± 0.46	4.12 ± 0.57	0.00*
CAL (mm)	3.34 ± 0.52	4.38 ± 0.61	0.00*
MR (mm)	0.39 ± 0.28	1.02 ± 0.47	0.00*

WKM (mm)	3.12 ± 0.42	1.16 ± 0.38	0.00*
CBL (mm)	1.28 ± 0.35	2.03 ± 0.41	0.00*

*Statistically significant

The stability of dental implants and the state of the surrounding soft and hard tissues are just as important to their long-term success as establishing osseointegration. There has been continuous discussion over the function of keratinized mucosa (KM), one of the several systemic and local elements affecting the state of the tissue around implants. There is increasing evidence that good peri-implant clinical outcomes are positively correlated with enough KM. This study thus sought to clarify the relationship between the width of keratinized mucosa (WKM) and critical radiographic and clinical outcomes related to the stability and health of dental implants [30, 31].

According to the current study's findings, implants with insufficient WKM (less than 2 mm) had noticeably worse peri-implant tissue characteristics than implants with sufficient WKM (more than 2 mm). Specifically, the inadequate WKM group showed elevated mean PI and GI scores, suggesting higher plaque accumulation and increased gingival inflammation. A deeper peri-implant sulcus and decreased tissue support were also indicated by the considerably higher probing depth and attachment loss in this group. Moreover, mucosal recession and radiographic bone loss were more severe in sites with insufficient WKM. These findings provide credence to the notion that maintaining the health of the region surrounding implants requires keratinized mucosa [32-35].

Implants with fewer than two millimeters of keratinized mucosa showed higher plaque and gingival indices, more bone loss, and a higher risk of bleeding, according to Bouri *et al*. [36] even after controlling for confounding factors. Their conclusions are supported by these findings. Similarly, Longoni *et al*. [37] in their thorough evaluation and meta-analysis, revealed that appropriate keratinized mucosa is substantially related with lower levels of gingival inflammation, while the relationship with bleeding and plaque buildup was less clear. Remarkably, their results also indicated an increased tendency for the ≥2 mm WKM group.

Our findings corroborate those of Ramanauskaite *et al*. [38] who demonstrated that a lower WKM is linked to an increased risk of bleeding, plaque accumulation, peri-implant diseases, and mucosal recession. Adibrad *et al*. [39] found that insufficient keratinized mucosa is linked to increased PI, GI, BOP, and recession, which is consistent with our findings and supports the protective function of WKM.

Numerous further research corroborate this relationship. Grischke *et al*. [40] discovered a strong correlation between reduced KM and the incidence and severity of peri-implant mucositis. WKM <2 mm is linked to negative clinical indices such GI, PI, and mucosal inflammation, according to Gobbato *et al*. [41] and Heydari *et al*. [42] despite the fact that the depth of peri-implant pockets showed inconsistent associations across studies. The functional importance of KM in regulating the emergence and remission of experimentally produced mucositis lesions was further highlighted by Schwarz *et al*. [43]

Furthermore, Zigdon *et al*. [44] demonstrated a negative correlation between WKM and mucosal recession, attachment loss, and pro-inflammatory biomarkers, highlighting the biological impact of KM width on soft tissue stability and inflammatory response. Additionally, Chiu *et al*. [45] observed that a lack of adequate KM can hinder proper oral hygiene maintenance, which may contribute to plaque retention and tissue inflammation. The clinical significance of KM in implant maintenance was further established by Kungsadalpipob *et al*. [46] who corroborated these findings in a large cross-sectional research. They reported greater probabilities of plaque buildup, mucosal recession, and interproximal bone loss in implants without keratinized mucosa.

Our study's thorough assessment of clinical and radiographic peri-implant parameters in connection to WKM, which provides a full picture of tissue health, is one of its main strengths. The inclusion of well-defined groups based on WKM width and the application of standardized measurement protocols add to the reliability of our findings. But because of the study's cross-sectional design, it is challenging to establish causality. The sample size, though adequate, may not fully represent diverse implant systems, mucosal biotypes, or long-term follow-up scenarios. Potentially influential patient-level factors, including oral hygiene, systemic health, and implant positioning, were not comprehensively assessed. It is advised that further longitudinal studies with bigger and more diverse populations be conducted to examine the impact of surgically augmenting the keratinized mucosa and to validate the protective function of WKM over time [47, 48]. Additionally, patient-centered outcomes such as discomfort during brushing or aesthetic concerns should also be evaluated to understand the functional significance of KM beyond clinical indices.

Conclusion

Within the constraints of this investigation, a strong correlation was found between the state of the soft and hard tissues around the implant and the breadth of the keratinized mucosa. Inadequate WKM sites (less than 2 mm) showed worse clinical results, such as higher gingival and plaque indices, deeper probing, more recession, and more bone loss. These findings highlight the need to ensure that adequate KM is included in implant treatment preparation and maintenance procedures, as well as the keratinized mucosa's possible protective function in preserving the integrity of the tissue around implants.

Acknowledgments: None

Conflict of interest: None

Financial support: None

Ethics statement: The study protocol was approved by Institutional Ethics Committee, Saveetha Dental College and Hospitals, Chennai, India (SDC/MSIMPLANT-2406/24/426).

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