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Determinants of keratinized mucosa dimensional changes after apically positioned flap surgery around dental implants

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Abstract (J Korean Assoc Oral Maxillofac Surg 2026;52:179-186)

Objectives: This study aimed to evaluate changes in keratinized mucosa width (KMW) following an apically positioned flap (APF) during implant placement and to identify factors associated with KMW gain (KMWG).

Patients and Methods: This retrospective single-center study included patients who underwent APF during implant placement. KMW was measured at baseline (BKMW), immediately after surgery (T1), and at 6 months after surgery (T2). Clinicodemographic and surgical factors were recorded, and univariable and multivariable generalized estimating equation (GEE) analyses were performed to identify factors associated with KMWG.

Results: This study included 78 patients with 207 implants. The mean BKMW was 1.09±1.54 mm, the mean T1 was 4.59±2.29 mm, the mean T2 was 2.71±1.70 mm, and the mean KMWG was 1.62±1.46 mm. In univariable GEE analysis, hypertension, periodontal phenotype, BKMW, and the amount of flap displacement (AFD) were associated with KMWG (P<0.05). In multivariable GEE analysis, hypertension (estimate=0.607, P=0.012), periodontal phenotype (estimate=0.603 for thick phenotype, P=0.014), and AFD (estimate=0.221, P=0.018) were positively associated with KMWG, whereas BKMW was negatively associated with KMWG (estimate=−0.349, P<0.001).

Conclusion: An increase in peri-implant KMW was observed after APF performed during implant placement. Clinicodemographic and surgical factors were associated with KMWG, suggesting that preoperative assessment may improve the predictability of peri-implant soft tissue augmentation and support surgical planning. Clinically meaningful KMWG could be achieved even with relatively limited flap extension when APF was performed using a standardized surgical approach.

Key words: Dental implants, Gingiva, Apically positioned flap surgery, Peri-implant soft tissue

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I. Introduction

Adequate peri-implant soft tissue support, particularly sufficient width and thickness of keratinized mucosa (KM), is considered important for the long-term maintenance of dental implants[1]. A sufficient band of KM around implants has been associated with reduced plaque accumulation, improved access for oral hygiene, protection against mechanical irritation, and enhanced peri-implant soft tissue stability. In general, insufficient KM may increase the risk of peri-implant inflammation and difficulty in plaque control[1-4].

With increasing recognition of the clinical importance of peri-implant KM, soft tissue management strategies have shifted from excisional approaches to tissue-preserving, repositioning, and augmentation techniques[5]. Various surgical procedures, such as the apically positioned flap (APF), free gingival graft, and connective tissue graft, have been proposed to increase the KM width (KMW) around implants[5,6]. Among these, APF offers several advantages, including relative technical simplicity, reduced patient morbidity, and predictable outcomes, as it repositions the existing keratinized tissue apically without requiring a donor site[5,7].

Although the optimal KMW required for peri-implant health remains controversial, several studies have suggested that a minimum of approximately 2 mm of KMW may be beneficial for long-term stability[8,9]. However, there is still limited evidence regarding the stability of KMW following

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APF and the clinicodemographic and surgical factors associated with KMW changes.

Therefore, this study aimed to evaluate changes in KMW following APF performed in conjunction with implant placement and to identify factors associated with the magnitude of KMW gain (KMWG). The working hypothesis was that APF would be associated with an increase in peri-implant KMW and that KMWG would be associated with clinicodemographic factors (age, sex, hypertension, diabetes mellitus, and smoking status) and surgical factors, including implant location (jaw and tooth region), periodontal phenotype, flap extension, baseline KMW (BKMW), KMW measured immediately after surgery (T1), and the amount of flap displacement (AFD).

II. Patients and Methods

1. Study design

This retrospective single-center study included patients who received APF procedures during implant surgery at the Department of Oral and Maxillofacial Surgery, Section of Dentistry, Seoul Metropolitan Government - Seoul National University Boramae Medical Center, Seoul, Republic of Korea. Patients treated between April 2017 and August 2025 were screened for eligibility. Cases without APF during implant surgery, those involving implants other than Osstem implants, records with incomplete clinical data, and cases with postoperative infection were excluded. Patients and implants meeting all eligibility criteria were included in the final analysis. The detailed patient and implant selection process is presented in the flow diagram.(Fig. 1)

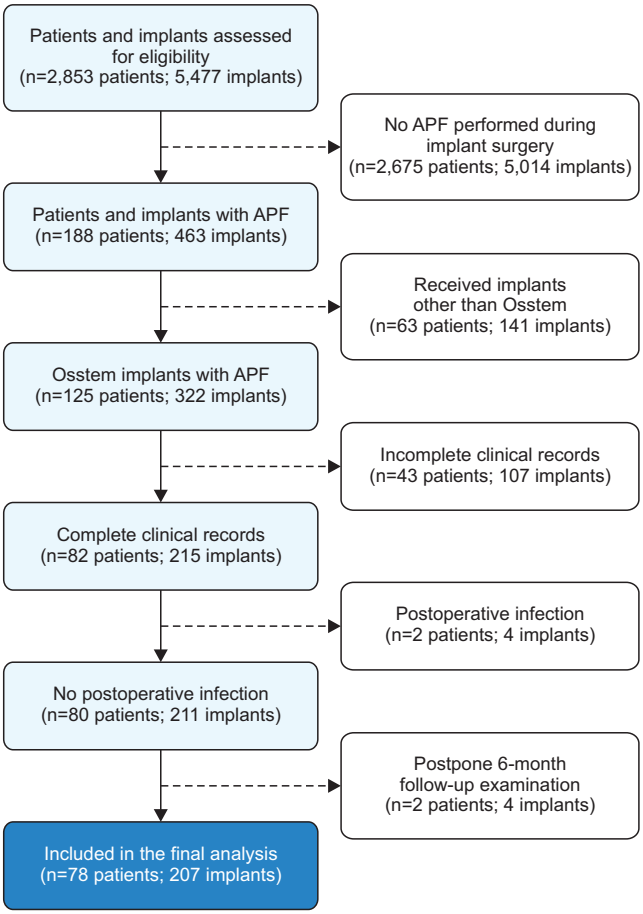


Fig. 1. Flow chart of case selection. (APF: apically positioned flap).
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2. Surgical procedure

All surgical procedures were performed by a single experienced surgeon (Y.S.H., corresponding author). During implant (Osstem TS III SA; Osstem) surgery, BKMW was measured as the distance between the mucogingival junction and the virtual implant healing abutment position.(Fig. 2. A) A buccal full-thickness mucoperiosteal flap was elevated and apically repositioned.(Fig. 2. B) A healing abutment was subsequently connected. The healing abutment diameters were standardized according to the implant region, with 4 mm healing abutments used in the anterior and premolar regions and 6 mm healing abutments used in the molar region. All implants were placed approximately 1 mm subcrestally. A delayed loading protocol was applied, and definitive prosthetic loading was performed 6 months after implant placement. The flap design and suturing aimed to preserve and apically reposition the existing KM rather than excise it. AFD was calculated as the difference between T1 and BKMW (AFD=T1−BKMW), representing the actual AFD immediately after surgery.(Fig. 2. C) Suturing was performed using 4-0 polyamide monofilament sutures (Dafilon; B.Braun Surgical, S.A.). Postoperative management included a short course of systemic antibiotics and analgesics.

3. Clinical evaluation and observation periods

KMW was measured at three time points.

1) Baseline KMW (BKMW)
2) KMW immediately after surgery (T1)
3) KMW 6 months after surgery (T2)

At each time point, KMW was measured separately for

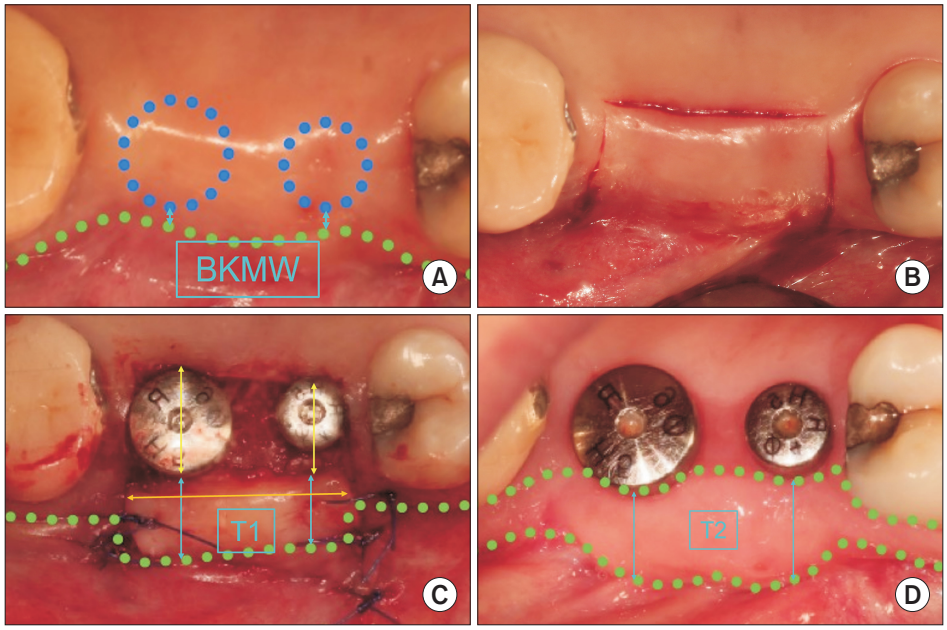


Fig. 2. Clinical photographs illustrating the apically positioned flap procedure and reference lines used for measurements. A. Preoperative view. The dotted circles indicate the virtual healing abutment positions. The dotted line represents the mucogingival junction. The distance between each virtual healing abutment position and the mucogingival junction (double-headed arrows) was defined as the baseline keratinized mucosa width (BKMW). B. Intraoperative view. A full-thickness incision was made toward the buccal side. C. Immediate postoperative view. The lower vertical double-headed arrows indicate the keratinized mucosa width immediately after surgery (T1). The the upper vertical double-headed arrows indicate the amount of flap displacement, and the the middle horizontal double-headed arrow indicates the flap extension. D. Six-month postoperative view. The double-headed arrows indicate the keratinized mucosa width at 6 months after surgery (T2).
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each implant site using a paper ruler with a resolution of 0.1 mm. BKMW was measured as the distance from the mucogingival junction to the virtual implant healing abutment position, whereas T1 and T2 were measured as the distance from the mucogingival junction to the buccal gingival margin. The T2 measurement was performed while the healing abutment was still in place, before prosthesis delivery.(Fig. 2. D) The T2 assessment was scheduled approximately 6 months after implant placement, with an allowable time window of ±0.5 months (5.5 to 6.5 months). All measurements were performed by a single calibrated examiner (Y.S.H.). Each measurement was performed twice at each time point on the same day, and the first measurement value was used for analysis. Intra-examiner reliability was assessed using the intraclass correlation coefficient (ICC) based on a two-way mixed-effects model for absolute agreement in thirty randomly selected implant sites[10].

The periodontal phenotype was classified as thin (≤1 mm) or thick (>1 mm) based on visual assessment and transgingival probing[11]. Additionally, variables including sex, age, hypertension status, diabetes mellitus status, smoking status, anatomical location (maxilla/mandible; anterior/premolar/molar), flap extension (mesiodistal width of the APF measured according to the number of prosthetic units involved in the flap design), AFD, and KMWG were recorded for analysis.(Fig. 2) KMWG was calculated as the difference between T2 and BKMW. When multiple implants were placed within the same APF surgical site, flap extension was shared among those implants, whereas AFD and periodontal phenotype were recorded individually for each implant site. Patient-level variables (hypertension, diabetes mellitus, and smoking status) were assigned identically to all implants from the same patient.

4. Statistical analysis

Statistical analyses were performed using SAS version 9.4 (SAS Institute Inc.), and statistical significance was set at $P<0.05$.

Demographic and clinical characteristics of the study subjects were summarized as frequencies and percentages for categorical variables and as means with standard deviations for continuous variables.

To identify factors associated with KMWG, univariable generalized estimating equation (GEE) analyses were performed for each independent variable. All candidate variables

were initially considered simultaneously in the multivariable GEE model. A stepwise variable selection procedure based on the quasi-likelihood under the independence model criterion (QIC) was used for multivariable model selection. The model with the lowest QIC value was selected as the final multivariable GEE model. The GEE approach was used to account for the correlation among implants within the same patient[12].

III. Results

A total of 78 patients and 207 implants were included in this study. The mean numbers of implants and APF surgical sites per patient were 2.65 (range, 1-14) and 1.51 (range, 1-6) respectively. The mean age of the patients was 65.08±11.24 years. Among them, 53 (67.95%) were male and 25 (32.05%) were female. Seven patients (8.97%) were smokers, while 71 (91.03%) were non-smokers. Hypertension was present in 28 patients (35.90%), and diabetes mellitus was reported in 12 patients (15.38%).(Table 1)

Regarding implant location and surgical characteristics, 106 implants (51.21%) were placed in the maxilla and 101 (48.79%) in the mandible. According to tooth region, 18 implants (8.70%) were located in the anterior region, 53 (25.60%) in the premolar region, and 136 (65.70%) in the molar region. In terms of flap extension, 61 sites (29.47%) involved a 1-unit span, 46 (22.22%) a 2-unit span, 54 (26.09%) a 3-unit span, 24 (11.59%) a 4-unit span, and 22 (10.63%) a 5-unit span.(Table 2)

The mean follow-up duration between implant placement and T2 measurement was 6.01±0.30 months. The mean BKMW was 1.09±1.54 mm, and the mean AFD was 4.38±1.21 mm. The mean T1 was 4.59±2.29 mm, and the mean T2 was 2.71±1.70 mm, resulting in a mean KMWG of 1.62±1.46 mm.(Table 2) At T2, 137 implants (66.18%) achieved a final KMW of ≥2 mm. A total of 31 implants (14.98%) showed no net gain in KMW, including 16 implants with no change and 15 implants with KMW reduction. The mean reduction of KMW from T1 to T2 was 1.88±1.43 mm. The ICC values were 0.981 (95% confidence interval [CI], 0.962-0.991) for BKMW, 0.925 (95% CI, 0.846-0.964) for T1, and 0.872 (95% CI, 0.749-0.937) for T2.

In the univariable GEE analyses, hypertension (estimate=0.659, *P*=0.015), periodontal phenotype (thick phenotype: estimate=0.855, *P*=0.002), BKMW (estimate=−0.413, *P*<0.001), and AFD (estimate=0.427, *P*<0.001) were significantly associated with KMWG.(Table 3)

Because the full multivariable GEE model did not converge due to sparsity and multicollinearity, QIC-based stepwise variable selection was performed[12]. In the final multivariable GEE model, hypertension (estimate=0.607, *P*=0.012), thick

Table 1. Clinicodemographic factors of the patients (n=78)

Independent variable	Value
Age (yr)	65.08±11.24
Sex	
Male	53 (67.95)
Female	25 (32.05)
Hypertension	
Yes	28 (35.90)
No	50 (64.10)
Diabetes mellitus	
Yes	12 (15.38)
No	66 (84.62)
Smoking status	
Yes	7 (8.97)
No	71 (91.03)

Values are presented as number (%) or mean±standard deviation.

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Table 2. Surgical factors related to apically positioned flap surgery (n=207)

Independent variable	Value	*P*-value[1]
Jaw		
Maxilla	106 (51.21)	
Mandible	101 (48.79)	
Tooth region		
Anterior	18 (8.70)	
Premolar	53 (25.60)	
Molar	136 (65.70)	
Periodontal phenotype		
Thin	57 (27.54)	
Thick	150 (72.46)	
Flap extension		
1 unit	61 (29.47)	
2 units	46 (22.22)	
3 units	54 (26.09)	
4 units	24 (11.59)	
5 units	22 (10.63)	
BKMW (mm)	1.09±1.54	
T1 (mm)	4.59±2.29	
T2 (mm)	2.71±1.70	
AFD (T1–BKMW, mm)	4.38±1.21	<0.001*
KMWG (T2–BKMW, mm)	1.62±1.46	<0.001*
T2-T1 (mm)	–1.88±1.43	<0.001*

(BKMW: baseline keratinized mucosa width, AFD: amount of flap displacement, T1: keratinized mucosa width immediately after surgery, T2: keratinized mucosa width at 6 months after surgery, KMWG: keratinized mucosa width gain)

Values are presented as number (%) or mean±standard deviation.

[1]Result of paired *t*-test.

*$P<0.05$.

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Table 3. Factors associated with keratinized mucosa width gain: univariable generalized estimating equations

Independent variable	Estimate	Standard error	95% confidence interval	*P*-value
Age	0.026	0.013	(0.000 to 0.052)	0.047*
Sex, female	–0.048	0.284	(–0.605 to 0.510)	0.867
Hypertension	0.659	0.270	(0.129 to 1.188)	0.015*
Diabetes mellitus	0.374	0.300	(–0.214 to 0.962)	0.213
Smoking	–0.385	0.524	(–1.412 to 0.642)	0.463
Jaw				
Mandible vs. Maxilla (ref)	–0.361	0.250	(–0.851 to 0.130)	0.150
Tooth region				
Anterior	–0.112	0.257	(–0.615 to 0.392)	0.665
Premolar	0.199	0.220	(–0.232 to 0.629)	0.365
Molar (ref)				
Periodontal phenotype, thick	0.855	0.272	(0.321 to 1.389)	0.002*
Flap extension	0.018	0.097	(–0.172 to 0.208)	0.853
BKMW	–0.413	0.085	(–0.581 to –0.246)	<0.001*
AFD	0.427	0.107	(0.216 to 0.637)	<0.001*

(BKMW: baseline keratinized mucosa width, AFD: amount of flap displacement)
*P<0.05.
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Table 4. Factors associated with keratinized mucosa width gain: multivariable generalized estimating equation

Independent variable	Estimate	Standard error	95% confidence interval	*P*-value
Hypertension	0.607	0.240	(0.136 to 1.077)	0.012
Periodontal phenotype, thick	0.603	0.245	(0.124 to 1.083)	0.014
BKMW	–0.349	0.076	(–0.499 to –0.200)	<0.001
AFD	0.221	0.093	(0.038 to 0.404)	0.018

(BKMW: baseline keratinized mucosa width, AFD: amount of flap displacement)
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periodontal phenotype (estimate=0.603, P=0.014), and AFD (estimate=0.221, P=0.018) were positively associated with KMWG, whereas BKMW was negatively associated with KMWG (estimate=−0.349, P<0.001).(Table 4)

IV. Discussion

Adequate peri-implant KM around dental implants has been associated with improved peri-implant health, reduced plaque accumulation and mucosal inflammation, and greater patient comfort during oral hygiene[1-4]. Various surgical approaches have been proposed to increase peri-implant KM, among which APF is considered a simple and predictable technique[5,7].

This study evaluated clinicodemographic and surgical factors associated with KMWG following APF. The multivariable GEE analysis identified hypertension, periodontal phenotype, BKMW, and AFD as variables significantly associated with KMWG.

In the present study, a mean KMWG of 1.62±1.46 mm was observed 6 months after APF performed in conjunction with implant surgery. Previous studies have reported KMWG ranging from approximately 1.9 to 4.0 mm following APF procedures, with Tarasenko et al.[13] reporting a mean gain of 1.93 mm and Reddy et al.[7] reporting a mean gain of 3.95 mm. The differences among studies may be attributed to variations in follow-up duration, surgical techniques, and baseline soft tissue characteristics. Unlike previous studies that primarily focused on the effectiveness of APF for increasing KMW, the present study additionally evaluated clinicodemographic and surgical factors associated with KMWG, providing further insight into the predictability of peri-implant soft tissue augmentation outcomes.

Periodontal phenotype was significantly associated with KMWG, with thicker phenotypes demonstrating greater KMWG than thinner phenotypes in the present study. This finding may be explained by the greater structural resilience and biologic stability of thick periodontal phenotypes, which have been associated with more favorable wound healing and soft tissue outcomes in previous studies[14-16]. Accordingly, preoperative assessment of soft tissue phenotype may be useful when estimating the potential outcomes of APF procedures.

AFD was positively associated with KMWG, suggesting that implants with greater AFD tended to show greater KMWG. This finding is consistent with the principal mechanism of APF, whereby the mucogingival complex is repositioned apically to increase the KMW. A greater AFD may allow a larger amount of crestal KM to be preserved without

excision and repositioned apically, thereby potentially allowing greater KMWG.

Interestingly, hypertension was positively associated with KMWG in the present study. Previous studies have suggested that angiotensin-converting enzyme inhibitors and angiotensin II receptor blockers may influence scar formation and tissue remodeling through modulation of fibrotic pathways, while antithrombotic agents may affect microcirculation and tissue viability by reducing thrombotic events[17-22]. These potential pharmacological effects may partly explain the observed association between hypertension and KMWG. However, this interpretation remains speculative, as hypertension itself may not directly indicate enhanced soft-tissue healing, and medication type, treatment duration, blood pressure control, and cardiovascular comorbidities were not evaluated in the present study. Further studies incorporating these factors are needed to clarify the factors underlying this association.

BKMW showed a negative association with KMWG, indicating that sites with smaller BKMW tended to exhibit greater postoperative gain. However, this finding should be interpreted cautiously because KMWG was calculated as the difference between T2 and BKMW. Therefore, the observed inverse association may partly reflect mathematical coupling, floor effects, or regression to the mean rather than a direct biological relationship. In particular, because BKMW is incorporated into the calculation of KMWG, lower values of BKMW inherently allow a greater range for measurable gain, whereas higher BKMW values may limit the magnitude of calculated gain.

This phenomenon may also be influenced by the floor effect. In sites with greater BKMW, postoperative contraction can be fully reflected in the measured change, including cases in which KMWG becomes negative. In contrast, in sites with minimal or absent BKMW, further reduction beyond zero cannot be adequately captured because KMW cannot take a negative value. Consequently, postoperative shrinkage may be underestimated in sites with limited baseline KM. Although sites with greater BKMW may retain a larger amount of KM after healing, their calculated KMWG may appear smaller because postoperative contraction is more completely represented in the analysis.

Alternatively, a biological explanation may also be considered. Sites with lower BKMW may contain a greater proportion of non-keratinized alveolar mucosa, which has been reported to exhibit faster epithelial turnover and enhanced wound-healing characteristics, including more rapid re-epithelialization and extracellular matrix remodeling[23]. Therefore, sites with a larger proportion of non-KM may undergo more active tissue repair with less postoperative contraction, potentially resulting in greater KMWG. However, this biological interpretation remains speculative, and further studies are required to clarify the mechanisms underlying the association between BKMW and postoperative KMW changes.

In contrast, other variables such as smoking and diabetes mellitus did not show a statistically significant association with KMWG. Although both factors are traditionally considered detrimental to wound healing, their lack of significance in this study may be attributed to sample characteristics, relatively controlled systemic conditions, or insufficient statistical power to detect small effect sizes[24,25]. Similarly, flap extension was not significantly associated with KMWG. Greater flap extension has been theoretically considered beneficial for wound healing by preserving vascular supply and facilitating flap adaptation[26,27]. However, the present findings suggest that clinically meaningful KMWG can be achieved even with relatively limited flap extension when APF is performed using a standardized surgical approach. Likewise, jaw location and tooth region did not significantly influence KMWG, suggesting that local anatomical differences in vascularity according to bone type may have a limited impact when standardized surgical protocols are applied.

This study is limited by its retrospective design and the potential for selection bias and uncontrolled confounders. In addition, the absence of a non-APF comparison group limits the ability to determine whether the observed KMW changes were attributable solely to the APF procedure. The relatively small number of smokers and patients with systemic conditions, particularly diabetes mellitus, as well as variability in disease control, may have limited the ability to detect the true effects of these factors on KMWG. Furthermore, detailed medication information, particularly regarding antihypertensive and antithrombotic agents, and information regarding concomitant bone grafting procedures were not consistently available; therefore, their potential influence on peri-implant soft tissue changes could not be evaluated. Finally, KMW measurements were performed in millimeters, and inherent measurement errors at the submillimeter level may have influenced the calculated KMW changes. Future prospective studies with larger and more balanced patient populations, appropriate comparison groups, and comprehensive clinical data are warranted to validate these findings.

V. Conclusion

The present study demonstrated that APF performed in conjunction with implant surgery was associated with an increase in peri-implant KMW. Several clinicodemographic and surgical factors, including hypertension, periodontal phenotype, BKMW, and AFD, were associated with KMWG, suggesting that preoperative assessment of these factors may improve the predictability of peri-implant soft tissue augmentation and facilitate surgical planning. In contrast, flap extension was not associated with KMWG, indicating that clinically meaningful KMWG can be achieved even with relatively limited flap extension when APF is performed using a standardized surgical approach. These findings may contribute to a better understanding of factors associated with KMWG following APF and support more predictable peri-implant soft tissue management. Further prospective studies are required to validate these findings and clarify the biological mechanisms underlying the observed associations.

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Authors' Contributions

S.L. wrote the manuscript, and J.J. collected the data and images. H.L. revised the manuscript, and Y.S.H. performed the surgical procedures and revised the manuscript. All authors read and approved the final manuscript.

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Ethics Approval and Consent to Participate

The study protocol was approved by the Institutional Review Board (IRB) of the Seoul Metropolitan Government - Seoul National University Boramae Medical Center (IRB No. 10-2025-87) and conducted in accordance with the ethical principles of the Declaration of Helsinki (as revised in 2024). The written informed consent was waived by the IRB due to the retrospective nature of the study.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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