

# Comparative Evaluation of Soft Tissue Augmentation Around Dental Implants Using Connective Tissue Grafts Versus Collagen Matrices

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## ABSTRACT:

### Background:

Adequate peri-implant soft tissue volume and an adequate WKM are essential for maintaining peri-implant tissue health, enhancing esthetics, and ensuring the long-term success of dental implants. Although autogenous connective tissue grafts (CTGs) remain the gold standard for peri-implant soft tissue augmentation, collagen matrices (CMs) have emerged as a less invasive alternative that reduces patient morbidity by eliminating the need for a donor site.

### Aim:

To compare the clinical effectiveness of CTGs and CMs for peri-implant soft tissue augmentation around dental implants

### Materials and Methods:

A prospective randomized comparative clinical study was conducted on 40 patients requiring peri-implant soft tissue augmentation. Participants were randomly allocated into two groups: Group A received autogenous CTG (n = 20), while Group B received porcine-derived collagen matrices CM (n = 20). Clinical parameters, including peri-implant mucosal thickness, width of keratinized mucosa (WKM), plaque index (PI), gingival index (GI), probing pocket depth (PPD), and Pink Esthetic Score (PES), were recorded at baseline, 3 months, and 6 months. Postoperative pain was assessed using the Visual Analog Scale (VAS), and patient satisfaction was evaluated at the 6-month follow-up. Statistical analysis was performed using independent-samples t-tests, repeated-measures ANOVA, and the Chi-square test, with statistical significance set at  $p < 0.05$ .

### Results:

Both treatment modalities produced significant improvements in peri-implant mucosal thickness and WKM from baseline to 6 months ( $p < 0.001$ ). However, the CTG group demonstrated significantly greater mucosal thickness gain ( $2.40 \pm 0.40$  mm vs.  $1.80 \pm 0.30$  mm;  $p = 0.002$ ) and a significantly greater increase in WKM ( $2.25 \pm 0.48$  mm vs.  $1.73 \pm 0.44$  mm;  $p < 0.001$ ) than the CM group. At 6 months, the CTG group also achieved significantly higher PES ( $12.60 \pm 1.20$  vs.  $11.40 \pm 1.30$ ;  $p = 0.004$ ). No significant intergroup differences were observed for PI, GI, or PPD at any follow-up interval ( $p > 0.05$ ). In contrast, patients treated with CM reported significantly lower postoperative pain throughout the first postoperative week ( $p < 0.001$ ) and demonstrated higher treatment satisfaction at 6 months (70.0% vs. 45.0% very satisfied;  $p = 0.038$ ).

#### Conclusion:

Both CTGs and CMs are effective treatment options for peri-implant soft tissue augmentation. CTGs provide superior gains in peri-implant mucosal thickness, WKW, and esthetic outcomes, whereas collagen matrices offer the advantages of reduced postoperative pain, greater patient satisfaction, and avoidance of donor-site surgery. Therefore, CTGs remain the preferred option when maximum soft tissue augmentation and esthetic enhancement are the primary treatment objectives, while CMs represent an effective minimally invasive alternative for patients in whom reduced surgical morbidity and improved postoperative comfort are prioritized.

**Keywords:** Collagen matrix, Connective tissue graft, Dental implants, Keratinized mucosa, Peri-implant soft tissue augmentation, Pink Esthetic Score

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## Introduction

Dental implants have become the preferred treatment modality for replacing missing teeth because of their high survival rates, functional efficiency, and favorable esthetic outcomes. Nevertheless, long-term implant success depends not only on successful osseointegration but also on the establishment and maintenance of healthy peri-implant soft tissues. Adequate peri-implant mucosal thickness and an appropriate width of keratinized mucosa (WKM) play crucial roles in preserving peri-implant tissue health, minimizing marginal bone loss, facilitating plaque control, and achieving optimal esthetic integration with the surrounding dentition [1,2].

Soft tissue deficiencies around dental implants may result from tooth extraction, trauma, periodontal disease, congenital defects, or post-surgical tissue remodeling. These deficiencies can lead to mucosal recession, a compromised emergence profile, food impaction, patient discomfort during oral hygiene procedures, and an increased susceptibility to peri-implant inflammation. Thin peri-implant mucosa has also been associated with greater crestal bone remodeling and inferior esthetic outcomes, particularly in the anterior maxillary region, where soft tissue harmony is of paramount importance [3, 4].

Peri-implant soft tissue augmentation has therefore become an integral component of

contemporary implant therapy. The primary objectives of soft tissue augmentation include increasing mucosal thickness, enhancing the WKM, improving peri-implant tissue stability, reducing mucosal recession, and optimizing esthetic outcomes. Various surgical approaches have been proposed, including free gingival grafts, pedicle flaps, acellular dermal matrices, xenogeneic collagen substitutes, and autogenous connective tissue grafts (CTGs) [5].

Among these techniques, autogenous CTGs are widely regarded as the gold standard because of their predictable ability to increase soft tissue volume, improve peri-implant esthetics, and maintain long-term tissue stability. CTGs exhibit excellent vascular integration and biocompatibility, resulting in consistent and predictable clinical outcomes. However, harvesting autogenous tissue from the palate requires a second surgical site, which may increase operative time and postoperative pain, bleeding, swelling, and overall patient morbidity. In addition, the amount of donor tissue available may be limited in certain patients [6, 7].

To overcome these limitations, collagen matrices (CMs) have been developed as biomaterial substitutes for autogenous grafts. These xenogeneic or bioengineered scaffolds are designed to promote cellular infiltration, angiogenesis, and soft tissue regeneration while eliminating donor-site morbidity. Their standardized composition, unlimited availability, shorter surgical time, and improved patient comfort have made them increasingly attractive for use in peri-implant plastic surgery. Nevertheless, concerns remain regarding their ability to achieve tissue volume augmentation and long-term dimensional stability comparable to those of CTGs [8].

Several clinical studies and systematic reviews have demonstrated that both CTGs and CMs are effective in increasing peri-implant mucosal thickness and improving esthetic outcomes. Although CTGs generally provide greater and

more stable soft tissue volume augmentation, CMs have been associated with favorable wound healing and significantly lower postoperative discomfort. Despite these encouraging findings, the available literature demonstrates considerable heterogeneity in surgical techniques, graft materials, outcome measures, and follow-up durations, making direct comparisons between studies challenging [9].

Given the increasing emphasis on minimally invasive implant therapy and patient-centered care, identifying an effective alternative to autogenous CTGs has become increasingly important. Comparative evaluation of CTGs and CMs is essential to determine whether CMs can provide clinical outcomes comparable to those of CTGs while reducing treatment-related morbidity and improving patient satisfaction [10].

Therefore, the present study aimed to compare the clinical effectiveness of autogenous CTGs and CMs for peri-implant soft tissue augmentation by evaluating peri-implant mucosal thickness, the WKW, peri-implant clinical parameters, esthetic outcomes, and patient-reported postoperative experiences.

## **Materials & Methods**

### **Study Design**

This prospective, randomized comparative clinical study was conducted to evaluate and compare the clinical effectiveness of autogenous CTGs & CMs for peri-implant soft tissue augmentation. The study was carried out in a single tertiary care centre after obtaining approval from the Institutional Ethics Committee. All participants provided written informed consent before enrollment. The study adhered to the principles outlined in the Declaration of Helsinki for research involving human participants.

### **Study Population**

A total of 40 systemically healthy patients requiring peri-implant soft tissue augmentation in conjunction with implant therapy were recruited.

Eligible participants were between 20 and 60 years of age and presented with inadequate peri-implant soft tissue thickness and/or insufficient WKW around healed implant sites or at the time of implant uncovering.

### Inclusion Criteria

Patients fulfilling the following criteria were included:

- Age between 20 and 60 years
- Presence of one or more dental implants requiring peri-implant soft tissue augmentation
- Good general health without systemic diseases affecting wound healing
- Adequate oral hygiene with a plaque index (PI)  $\leq 1$
- Ability and willingness to attend scheduled follow-up visits
- Written informed consent

### Exclusion Criteria

- Patients were excluded if they had:
- Uncontrolled systemic diseases such as diabetes mellitus
- Pregnancy or lactation
- Current smoking or tobacco use
- Active periodontal or peri-implant disease
- History of head and neck radiotherapy
- Long-term corticosteroid or immunosuppressive therapy
- Allergy to collagen-based biomaterial
- Poor oral hygiene or inability to maintain plaque control
- Randomization and Group Allocation

The enrolled patients were randomly assigned into two equal groups ( $n = 20$  each) using a computer-generated randomization sequence. Allocation concealment was achieved using sequentially numbered, opaque, sealed envelopes opened immediately before surgery.

- **Group A (CTG Group):** Patients underwent peri-implant soft tissue augmentation using an autogenous CTG harvested from the palate.
- **Group B (CM Group):** Patients received a porcine-derived resorbable CM for soft tissue augmentation.

### Surgical Procedure

All surgical procedures were performed by the same experienced dental surgeon under local anesthesia to minimize operator-related variability.

A crestal incision with limited releasing incisions was made to elevate a partial-thickness flap around the implant site. In Group A, a subepithelial CTG was harvested from the palatal donor site using the single-incision technique. The graft was trimmed to the required dimensions, positioned over the peri-implant recipient bed, and stabilized with resorbable sutures before flap closure.

In Group B, the CM was hydrated in sterile saline according to the manufacturer's instructions and adapted over the prepared recipient site. The matrix was stabilized with resorbable sutures, and the flap was repositioned to achieve tension-free primary closure.

### Postoperative Care

All patients received standardized postoperative instructions. Analgesics (ibuprofen 400 mg as required) and 0.12% chlorhexidine mouth rinse twice daily for two weeks were prescribed. Mechanical plaque control at the surgical site was avoided for the first two weeks. Sutures were removed 10–14 days after surgery, and patients were enrolled in a supportive maintenance program throughout the study period.

### Clinical Evaluation

Clinical examinations were performed at baseline, 3 months, and 6 months by a calibrated examiner who was not involved in the surgical procedures.

The following parameters were recorded:

- Peri-implant mucosal thickness (mm): Measured using a standardized transgingival probing technique with an endodontic spreader and digital caliper
- WKM (mm): Measured from the free gingival margin to the mucogingival junction using a calibrated periodontal probe
- PI: Assessed according to the Silness and L  e Plaque Index
- Gingival Index (GI): Recorded using the L  e and Silness Gingival Index
- Probing Pocket Depth (PPD): Measured at six sites around each implant using a standardized periodontal probe
- Pink Esthetic Score (PES): Evaluated using the criteria proposed by F  rhauser et al. to assess peri-implant soft tissue esthetics.

### Patient-Reported Outcome Measures

Postoperative pain was assessed using a 10-cm Visual Analog Scale (VAS) on postoperative days 1, 3, and 7. Overall patient satisfaction regarding comfort and treatment acceptance was evaluated at the 6-month follow-up using a standardized questionnaire with a five-point Likert scale.

### Statistical Analysis

The data obtained in the present study were entered into a Microsoft Excel spreadsheet and subsequently analyzed using the Statistical Package for the Social Sciences (SPSS), version 26.0 (IBM Corp., Armonk, NY, USA). Data were checked for completeness, accuracy, and consistency before statistical analysis.

Continuous variables, including age, peri-implant mucosal thickness, WKM, PI, GI, PPD, PES, and VAS pain scores, were summarized using mean and standard deviation (mean  $\pm$  SD). Categorical variables, including sex and patient satisfaction categories, were presented as frequencies and percentages. The normality of continuous variables was assessed using the Shapiro–Wilk test

for normally distributed continuous variables, parametric statistical tests were applied. For comparison of continuous variables between the two independent study groups—Group A, treated with CTG, and Group B, treated with CM—the independent-samples Student's t-test was used. This test was applied for intergroup comparisons of age, peri-implant mucosal thickness, WKM, PI, GI, PPD, PES, and VAS pain scores, pain scores, and the magnitude of clinical gain between the two treatment groups.

For the assessment of changes in continuous clinical parameters measured repeatedly within the same group at baseline, 3 months, and 6 months, repeated-measures analysis of variance (repeated-measures ANOVA) was used. This analysis was applied separately within each treatment group for peri-implant mucosal thickness, WKM, PI, GI, PPD, PES, and VAS pain scores.

Postoperative VAS pain scores assessed on days 1, 3, and 7 were compared between the CTG and CM groups using the independent-samples t-test at each postoperative time point.

Categorical variables were analyzed using the Chi-square test of independence. The Chi-square test was used to compare sex distribution and patient satisfaction categories between the two treatment groups. When the expected frequency in any cell was less than 5, Fisher's exact test or the Fisher–Freeman–Halton exact test was considered more appropriate.

All statistical tests were two-tailed. A p-value of less than 0.05 was considered statistically significant, whereas a p-value of less than 0.001 was considered highly statistically significant. Results with  $p \geq 0.05$  were considered statistically non-significant.

### Results

Table 1 & Figure 1 summarize the baseline demographic characteristics of the study participants. Group A, treated with CTG, and Group B, treated with CM, each included 20 participants. The mean age of participants was

39.45  $\pm$  9.12 years in Group A and 40.10  $\pm$  8.76 years in Group B. Statistical analysis demonstrated no significant difference in age between the two groups ( $t = 0.230$ ,  $p = 0.819$ ), indicating that the study groups were well matched with respect to age. With regard to sex distribution, Group A included 11 males (55.0%) and 9 females (45.0%), while Group B comprised 10 males (50.0%) and

10 females (50.0%). The difference in the proportion of males and females between the groups was not statistically significant ( $\chi^2 = 0.100$ ,  $p = 0.752$ ). Overall, the absence of significant differences in age and sex confirms that the two treatment groups were comparable at baseline, minimizing the likelihood of demographic factors influencing the study outcomes.

**Table 1: Comparison of demographic characteristics between the study groups**

| Variable                   | Group A: CTG (n=20) | Group B: CM (n=20) | Test value       | p-value |
|----------------------------|---------------------|--------------------|------------------|---------|
| Age (years), Mean $\pm$ SD | 39.45 $\pm$ 9.12    | 40.10 $\pm$ 8.76   | $t = 0.230$      | 0.819   |
| Male, n (%)                | 11 (55.0)           | 10 (50.0)          | $\chi^2 = 0.100$ | 0.752   |
| Female, n (%)              | 9 (45.0)            | 10 (50.0)          |                  |         |

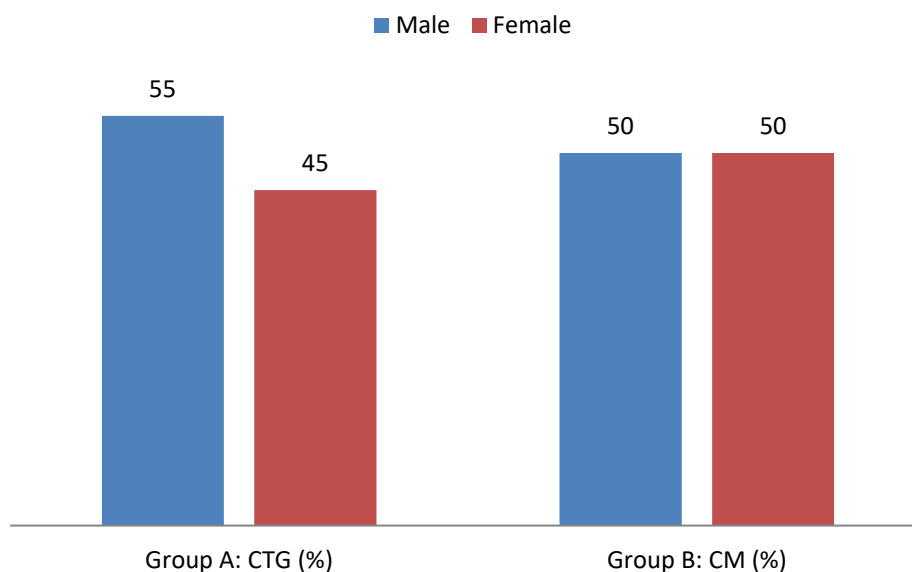


**Figure 1: Baseline Demographic Comparison of the Two Study Groups**

Table 2 & Figure 2 present the comparison of peri-implant mucosal thickness between Group A CTGs & CMs at baseline, 3 months, and 6 months following treatment. At baseline, the mean peri-implant mucosal thickness was 1.20  $\pm$  0.25 mm in Group A and 1.18  $\pm$  0.23 mm in Group B. The difference was not statistically significant ( $t = 0.263$ ,  $p = 0.794$ ), confirming that both groups had comparable baseline tissue thickness. At the 3-month follow-up, mucosal

thickness increased in both groups, reaching 2.85  $\pm$  0.38 mm in the CTGs group and 2.48  $\pm$  0.32 mm in the CMs group. The difference between the groups was statistically significant ( $t = 3.331$ ,  $p = 0.002$ ), indicating greater tissue thickening in the CTG group.

By 6 months, a further increase in peri-implant mucosal thickness was observed in both treatment groups. The mean thickness measured 3.60  $\pm$  0.42

mm in Group A compared with  $2.98 \pm 0.35$  mm in Group B. This difference was highly statistically significant ( $t = 5.073$ ,  $p < 0.001$ ).

Overall, both treatment approaches effectively enhanced peri-implant mucosal thickness over

time. However, the CTGs produced a significantly greater increase than the CMs, with the most pronounced difference observed at the 6-month evaluation.

**Table 2: Intergroup comparison of peri-implant mucosal thickness at different time intervals**

| Time interval | Group A: CTGs Mean $\pm$ SD (mm) | Group B: CMs Mean $\pm$ SD (mm) | t-value | p-value |
|---------------|----------------------------------|---------------------------------|---------|---------|
| Baseline      | $1.20 \pm 0.25$                  | $1.18 \pm 0.23$                 | 0.263   | 0.794   |
| 3 months      | $2.85 \pm 0.38$                  | $2.48 \pm 0.32$                 | 3.331   | 0.002*  |
| 6 months      | $3.60 \pm 0.42$                  | $2.98 \pm 0.35$                 | 5.073   | <0.001* |

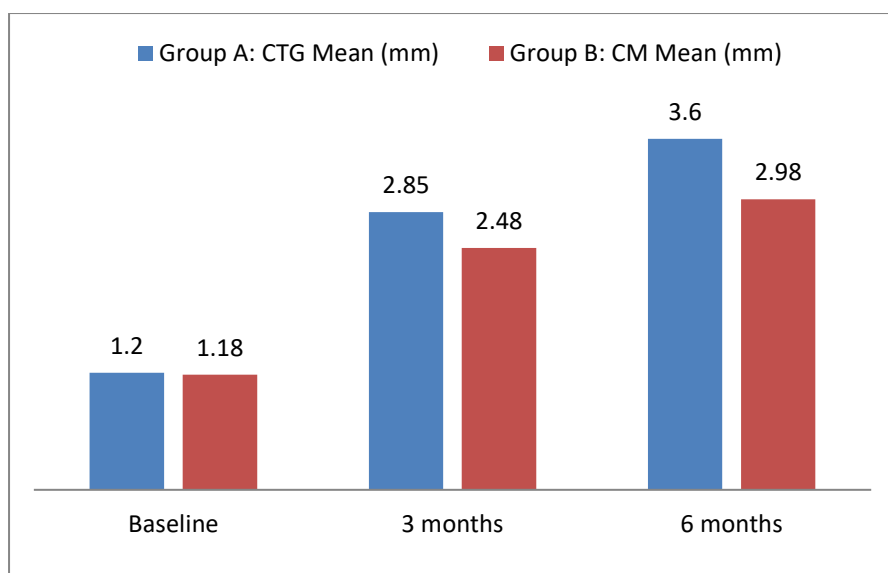


**Figure 2: Intergroup Comparison of Peri-Implant Mucosal Thickness at Baseline, 3 Months, and 6 Months**

Table 3 & Figure 3 illustrate the changes in peri-implant mucosal thickness within each treatment group at baseline, 3 months, and 6 months. In Group A (CTGs), the mean peri-implant mucosal thickness increased from  $1.20 \pm 0.25$  mm at baseline to  $2.85 \pm 0.38$  mm at 3 months and further to  $3.60 \pm 0.42$  mm at 6 months. The overall mean gain in mucosal thickness was  $2.40 \pm 0.40$  mm, with the improvement over time being highly statistically significant ( $p < 0.001$ ). In Group B (CMs), the mean peri-implant mucosal thickness increased from  $1.18 \pm 0.23$  mm at

baseline to  $2.48 \pm 0.32$  mm at 3 months and  $2.98 \pm 0.35$  mm at 6 months. The overall mean increase was  $1.80 \pm 0.30$  mm, and the changes across the follow-up period were also highly statistically significant ( $p < 0.001$ ). These findings demonstrate that both CTGs & CMs significantly improved peri-implant mucosal thickness over time. However, the CTG group exhibited a greater magnitude of tissue augmentation, with a mean gain of 2.40 mm compared with 1.80 mm in the CMs group.

**Table 3: Intragroup changes in peri-implant mucosal thickness**

| Group        | Baseline Mean<br>± SD | 3 months<br>Mean ± SD | 6 months<br>Mean ± SD | Overall<br>change | p-value |
|--------------|-----------------------|-----------------------|-----------------------|-------------------|---------|
| Group A: CTG | 1.20 ± 0.25           | 2.85 ± 0.38           | 3.60 ± 0.42           | 2.40 ± 0.40       | <0.001* |
| Group B: CM  | 1.18 ± 0.23           | 2.48 ± 0.32           | 2.98 ± 0.35           | 1.80 ± 0.30       | <0.001* |

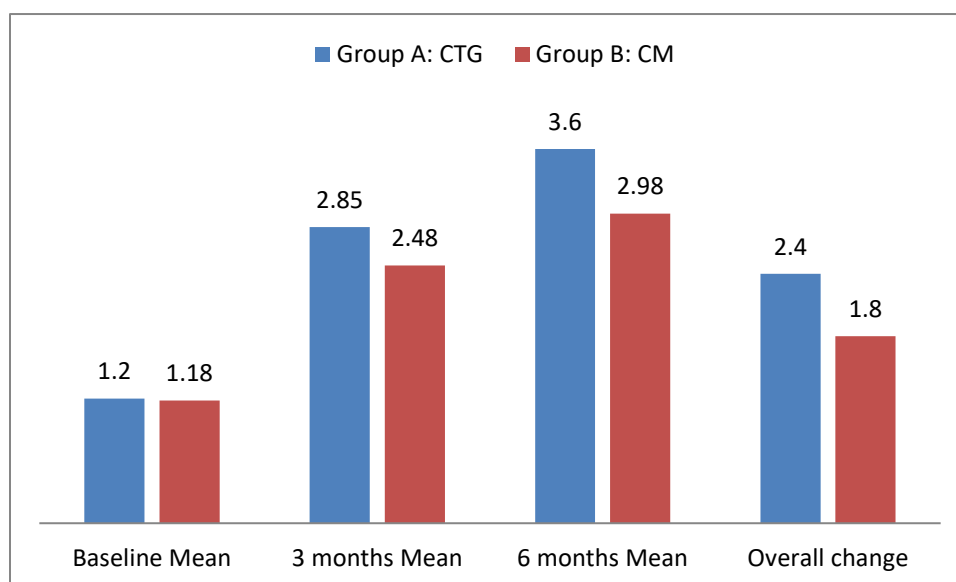
**Figure 3: Intragroup Comparison of Peri-Implant Mucosal Thickness at Baseline, 3 Months, and 6 Months**

Table 4 & Figure 4 illustrate the comparison of the overall gain in peri-implant mucosal thickness between the two study groups at the 6-month follow-up. The CTG group exhibited a mean increase in mucosal thickness of  $2.40 \pm 0.40$  mm, whereas the CM group showed a mean increase of  $1.80 \pm 0.30$  mm.

The difference in mean mucosal thickness gain between the two groups was 0.60 mm, favoring the CTG group, and this difference was statistically significant ( $t = 3.382$ ,  $p = 0.002$ ). Although both treatment modalities were effective in improving peri-implant mucosal thickness, the CTG group demonstrated a significantly greater increase than the CM group. These findings indicate that autogenous CTG provides superior soft tissue augmentation when greater peri-implant mucosal thickness is the desired clinical outcome.

**Table 4: Comparison of gain in peri-implant mucosal thickness at 6 months**

| Outcome                     | Group A: CTG<br>Mean ± SD | Group B: CM<br>Mean ± SD | t-value | p-value |
|-----------------------------|---------------------------|--------------------------|---------|---------|
| Mucosal thickness gain (mm) | $2.40 \pm 0.40$           | $1.80 \pm 0.30$          | 3.382   | 0.002*  |

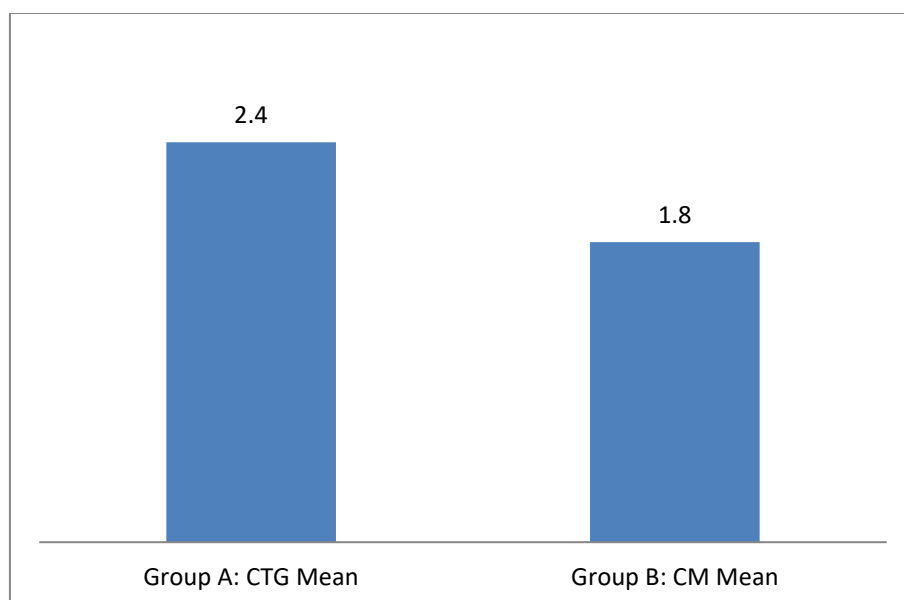


**Figure 4: Comparison of Mean Gain in Peri-implant Mucosal Thickness Between the CTG and CM Groups at 6 Months**

Table 5 & Figure 5 illustrate the comparison of WKM between the CTG and CM groups at baseline, 3 months, and 6 months. At baseline, the mean WKM was  $2.10 \pm 0.45$  mm in the CTG group and  $2.05 \pm 0.42$  mm in the CM group. No statistically significant difference was observed between the groups ( $t = 0.363$ ,  $p = 0.718$ ), indicating comparable baseline values.

At the 3-month follow-up, both groups demonstrated an increase in WKM. The mean WKM was  $3.85 \pm 0.52$  mm in the CTG group and  $3.48 \pm 0.49$  mm in the CM group. The difference between the groups was statistically significant ( $t$

$= 2.315$ ,  $p = 0.026$ ), with the CTG group exhibiting a greater increase.

At the 6-month follow-up, WKM continued to improve in both groups. The CTG group showed a mean WKM of  $4.35 \pm 0.55$  mm, whereas the CM group recorded a mean value of  $3.78 \pm 0.51$  mm. This intergroup difference remained statistically significant ( $t = 3.398$ ,  $p = 0.002$ ). Overall, both treatment modalities were effective in increasing the WKM; however, the CTG group achieved significantly greater improvement than the CM group throughout the follow-up period.

**Table 5: Intergroup comparison of WKM**

| Time interval | Group A: CTG Mean $\pm$ SD (mm) | Group B: CM Mean $\pm$ SD (mm) | t-value | p-value |
|---------------|---------------------------------|--------------------------------|---------|---------|
| Baseline      | $2.10 \pm 0.45$                 | $2.05 \pm 0.42$                | 0.363   | 0.718   |
| 3 months      | $3.85 \pm 0.52$                 | $3.48 \pm 0.49$                | 2.315   | 0.026*  |
| 6 months      | $4.35 \pm 0.55$                 | $3.78 \pm 0.51$                | 3.398   | 0.002*  |

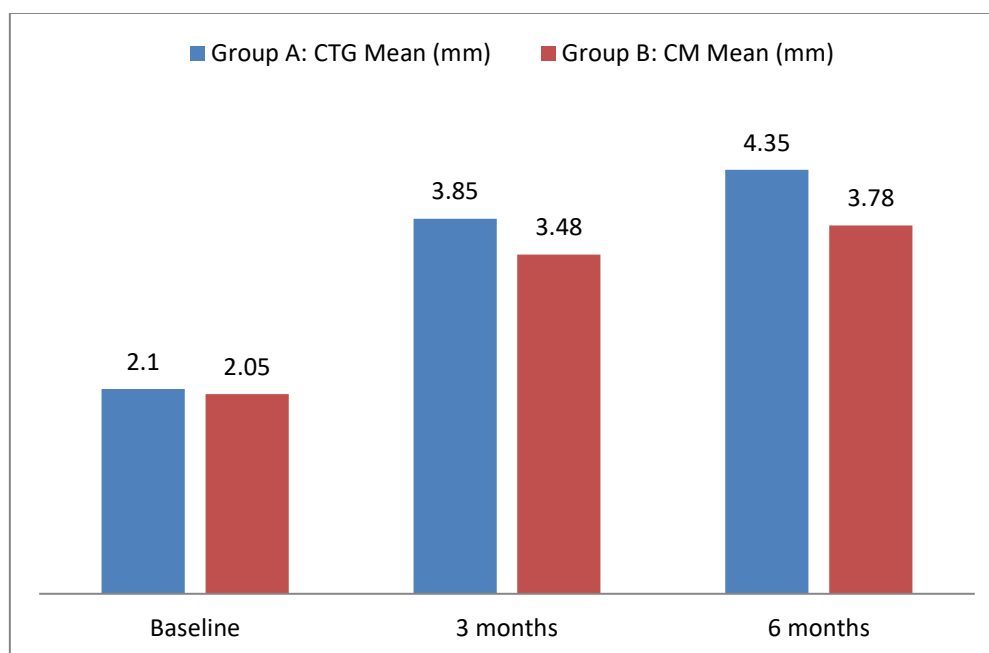


**Figure 5: Comparison of Mean WKM between the CTG and CM Groups at Baseline, 3 Months, and 6 Months**

Table 6 & Figure 6 illustrate the changes in the WKM over the 6-month follow-up period in both treatment groups. In Group A, the mean WKM increased from  $2.10 \pm 0.45$  mm at baseline to  $3.85 \pm 0.52$  mm at 3 months, reaching  $4.35 \pm 0.55$  mm at 6 months. This represented a mean overall gain of  $2.25 \pm 0.48$  mm, which was highly statistically significant ( $p < 0.001$ ).

Similarly, Group B demonstrated a significant increase in WKM, with the mean value rising from  $2.05 \pm 0.42$  mm at baseline to  $3.48 \pm 0.49$  mm at

3 months and  $3.78 \pm 0.51$  mm at 6 months. The mean overall increase was  $1.73 \pm 0.44$  mm, and the improvement was also highly statistically significant ( $p < 0.001$ ).

Overall, both treatment modalities resulted in significant enhancement of the WKW. However, the greater increase observed in Group A suggests that CTG achieved more effective augmentation of the peri-implant keratinized mucosa than the CM over the 6-month evaluation period.

**Table 6: Intragroup changes in WKW**

| Group        | Baseline Mean $\pm$ SD | 3 months Mean $\pm$ SD | 6 months Mean $\pm$ SD | Gain at 6 months | p-value    |
|--------------|------------------------|------------------------|------------------------|------------------|------------|
| Group A: CTG | $2.10 \pm 0.45$        | $3.85 \pm 0.52$        | $4.35 \pm 0.55$        | $2.25 \pm 0.48$  | $<0.001^*$ |
| Group B: CM  | $2.05 \pm 0.42$        | $3.48 \pm 0.49$        | $3.78 \pm 0.51$        | $1.73 \pm 0.44$  | $<0.001^*$ |

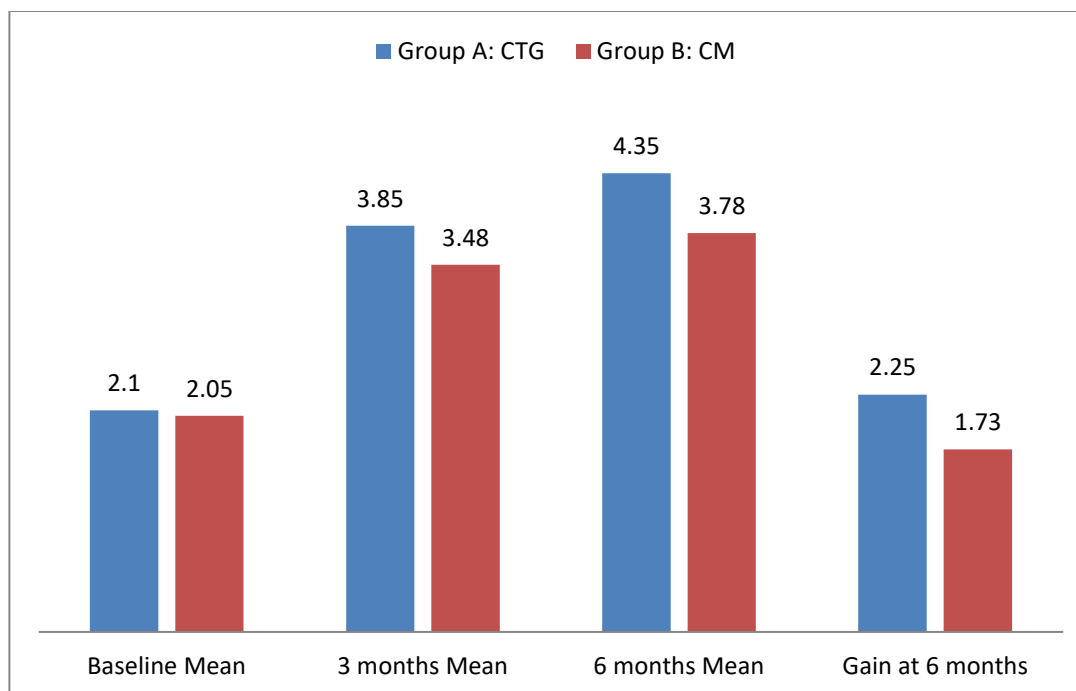


**Figure 6: Longitudinal changes in the WKM at baseline, 3 months, and 6 months in Groups A and B**

Table 7 & Figure 7 compare the PI scores between the CTG and CM groups at baseline and throughout the follow-up period. At baseline, the mean PI was  $0.68 \pm 0.21$  in Group A and  $0.70 \pm 0.23$  in Group B, with no statistically significant difference between the groups ( $t = 0.287$ ,  $p = 0.776$ ).

After 3 months, the mean PI decreased to  $0.54 \pm 0.18$  in Group A and  $0.56 \pm 0.20$  in Group B. The intergroup difference remained statistically non-significant ( $t = 0.332$ ,  $p = 0.742$ ). By 6 months, a further reduction in plaque accumulation was observed, with mean PI values of  $0.48 \pm 0.17$  for Group A and  $0.50 \pm 0.18$  for Group B. This difference was also not statistically significant ( $t = 0.361$ ,  $p = 0.720$ ).

Both treatment groups showed a gradual decline in PI scores over the 6-month follow-up period, indicating improved plaque control with time. However, no significant differences were observed between the CTG and CM groups at any evaluation point, suggesting that both treatment approaches were equally effective in maintaining plaque control throughout the study.

**Table 7: Intergroup comparison of PI**

| Time interval | Group A: CTG<br>Mean $\pm$ SD | Group B: CM<br>Mean $\pm$ SD | t-value | p-value |
|---------------|-------------------------------|------------------------------|---------|---------|
| Baseline      | $0.68 \pm 0.21$               | $0.70 \pm 0.23$              | 0.287   | 0.776   |
| 3 months      | $0.54 \pm 0.18$               | $0.56 \pm 0.20$              | 0.332   | 0.742   |
| 6 months      | $0.48 \pm 0.17$               | $0.50 \pm 0.18$              | 0.361   | 0.720   |

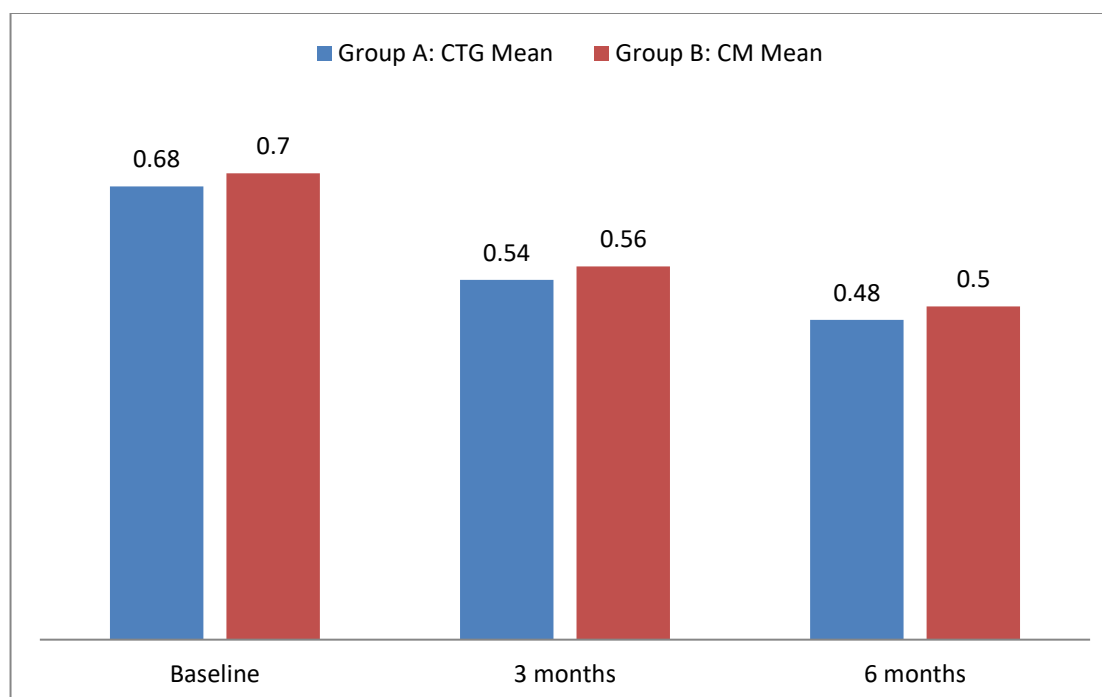


**Figure 7: Comparison of PI scores between the CTG and CM groups at baseline, 3 months, and 6 months**

Table 8 & Figure 8 illustrate the comparison of GI scores between the CTG and CM groups at baseline and during the 6-month follow-up period. At baseline, the mean GI was  $0.72 \pm 0.24$  in Group A and  $0.74 \pm 0.22$  in Group B, with no statistically significant difference between the groups ( $t = 0.275$ ,  $p = 0.785$ ).

At the 3-month evaluation, the mean GI decreased to  $0.50 \pm 0.19$  in Group A and  $0.52 \pm 0.18$  in Group B. The difference between the groups remained statistically non-significant ( $t = 0.342$ ,  $p = 0.734$ ). By 6 months, GI scores showed a further reduction to  $0.40 \pm 0.16$  in Group A and  $0.42 \pm 0.17$  in Group B. This difference also did not reach statistical significance ( $t = 0.383$ ,  $p = 0.704$ ).

Both groups exhibited a steady reduction in GI scores throughout the study, reflecting improved peri-implant gingival health over time. Nevertheless, no statistically significant differences were detected between the CTG and CM groups at any follow-up interval, indicating that both treatment modalities were similarly effective in reducing peri-implant gingival inflammation.

**Table 8: Intergroup comparison of GI**

| Time interval | Group A: CTG Mean $\pm$ SD | Group B: CM Mean $\pm$ SD | t-value | p-value |
|---------------|----------------------------|---------------------------|---------|---------|
| Baseline      | $0.72 \pm 0.24$            | $0.74 \pm 0.22$           | 0.275   | 0.785   |
| 3 months      | $0.50 \pm 0.19$            | $0.52 \pm 0.18$           | 0.342   | 0.734   |
| 6 months      | $0.40 \pm 0.16$            | $0.42 \pm 0.17$           | 0.383   | 0.704   |

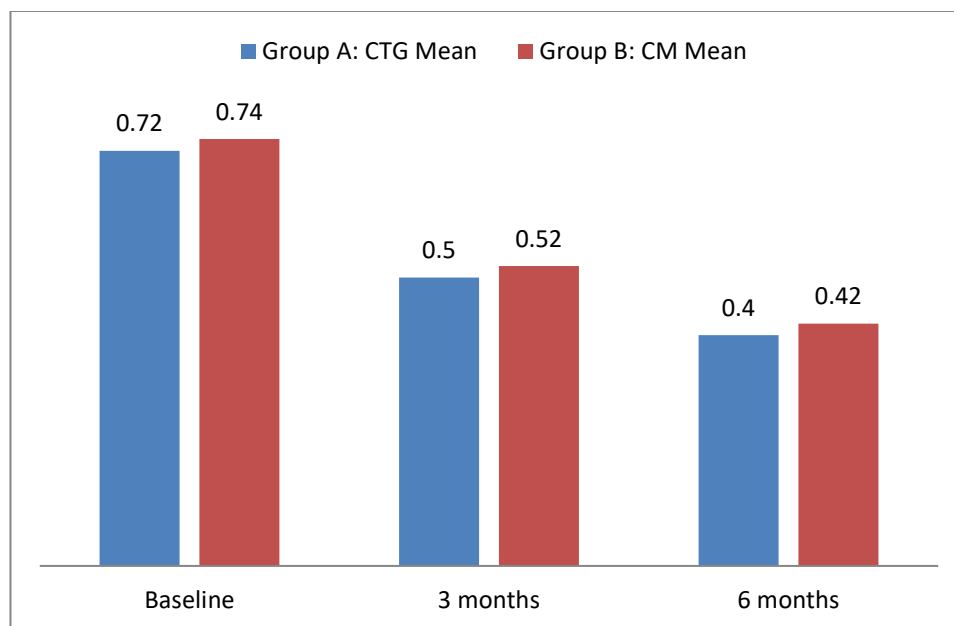


**Figure 8: Comparison of GI scores between the CTG and CM groups at baseline, 3 months, and 6 months**

Table 9 & Figure 9 compare the PPD between the CTG and CM groups at baseline and during the 6-month follow-up period. At baseline, the mean PPD was  $3.15 \pm 0.48$  mm in Group A and  $3.20 \pm 0.45$  mm in Group B, with no statistically significant difference between the groups ( $t = 0.340$ ,  $p = 0.736$ ).

At the 3-month follow-up, the mean PPD decreased to  $2.90 \pm 0.42$  mm in Group A and  $2.95 \pm 0.44$  mm in Group B. The difference between the groups remained statistically non-significant ( $t = 0.368$ ,  $p = 0.715$ ). By 6 months, the mean PPD further decreased to  $2.75 \pm 0.40$  mm in the CTG

group and  $2.80 \pm 0.41$  mm in the CM group. This intergroup difference was also not statistically significant ( $t = 0.390$ ,  $p = 0.699$ ).

Both treatment groups demonstrated a progressive reduction in PPD throughout the study period, indicating favorable peri-implant tissue healing. However, no significant differences were observed between the CTG and CM groups at any follow-up interval, suggesting that both treatment modalities achieved comparable improvements in PPD depth over the 6-month evaluation period.

**Table 9: Intergroup comparison of PPD**

| Time interval | Group A: CTG Mean $\pm$ SD (mm) | Group B: CM Mean $\pm$ SD (mm) | t-value | p-value |
|---------------|---------------------------------|--------------------------------|---------|---------|
| Baseline      | $3.15 \pm 0.48$                 | $3.20 \pm 0.45$                | 0.340   | 0.736   |
| 3 months      | $2.90 \pm 0.42$                 | $2.95 \pm 0.44$                | 0.368   | 0.715   |
| 6 months      | $2.75 \pm 0.40$                 | $2.80 \pm 0.41$                | 0.390   | 0.699   |

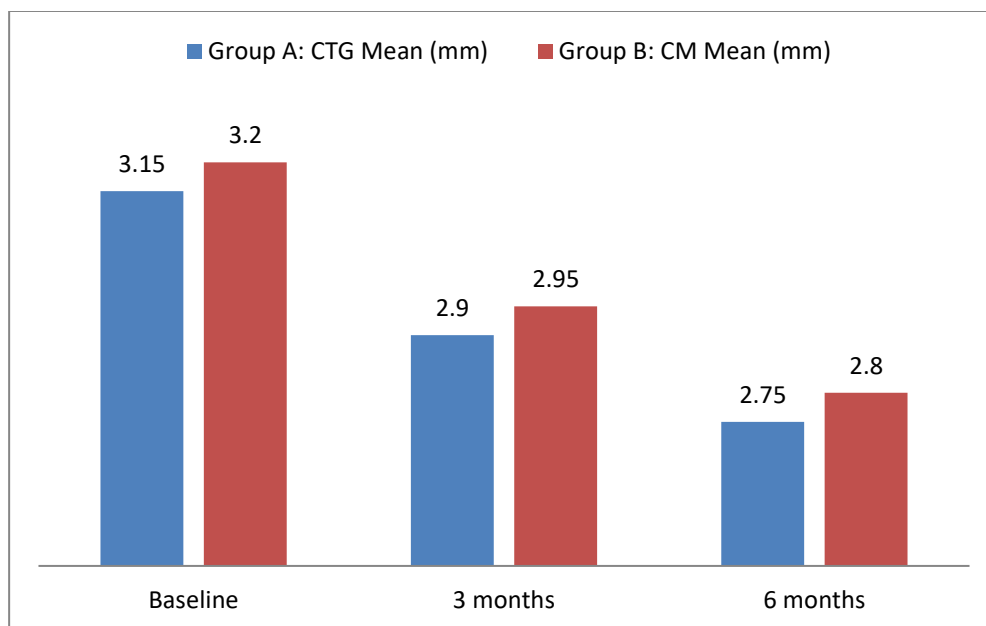


**Figure 9: Comparison of PPD between the CTG and CM groups at baseline, 3 months, and 6 months**

Table 10 & Figure 10 present the comparison of PES between the CTG and CM groups at baseline and during the 6-month follow-up period. At baseline, the mean PES was  $8.20 \pm 1.30$  in Group A and  $8.10 \pm 1.25$  in Group B, with no statistically significant difference between the groups ( $t = 0.248$ ,  $p = 0.805$ ), indicating similar esthetic conditions before treatment.

At the 3-month evaluation, the mean PES increased to  $10.80 \pm 1.25$  in the CTG group and  $10.10 \pm 1.20$  in the CM group. Although Group A demonstrated a higher mean score, the difference between the groups was not statistically significant ( $t = 1.806$ ,  $p = 0.079$ ).

By the 6-month follow-up, the mean PES had increased further to  $12.60 \pm 1.20$  in Group A, compared with  $11.40 \pm 1.30$  in Group B. This difference was statistically significant, indicating superior esthetic outcomes in the CTG group.

Overall, both treatment modalities produced marked improvements in peri-implant soft tissue esthetics over the study period. However, CTG resulted in significantly better esthetic outcomes than the CM at the final 6-month assessment.

**Table 10: Intergroup comparison of PES**

| Time interval | Group A: CTG Mean $\pm$ SD | Group B: CM Mean $\pm$ SD | t-value | p-value |
|---------------|----------------------------|---------------------------|---------|---------|
| Baseline      | $8.20 \pm 1.30$            | $8.10 \pm 1.25$           | 0.248   | 0.805   |
| 3 months      | $10.80 \pm 1.25$           | $10.10 \pm 1.20$          | 1.806   | 0.079   |
| 6 months      | $12.60 \pm 1.20$           | $11.40 \pm 1.30$          | 3.034   | 0.004†  |

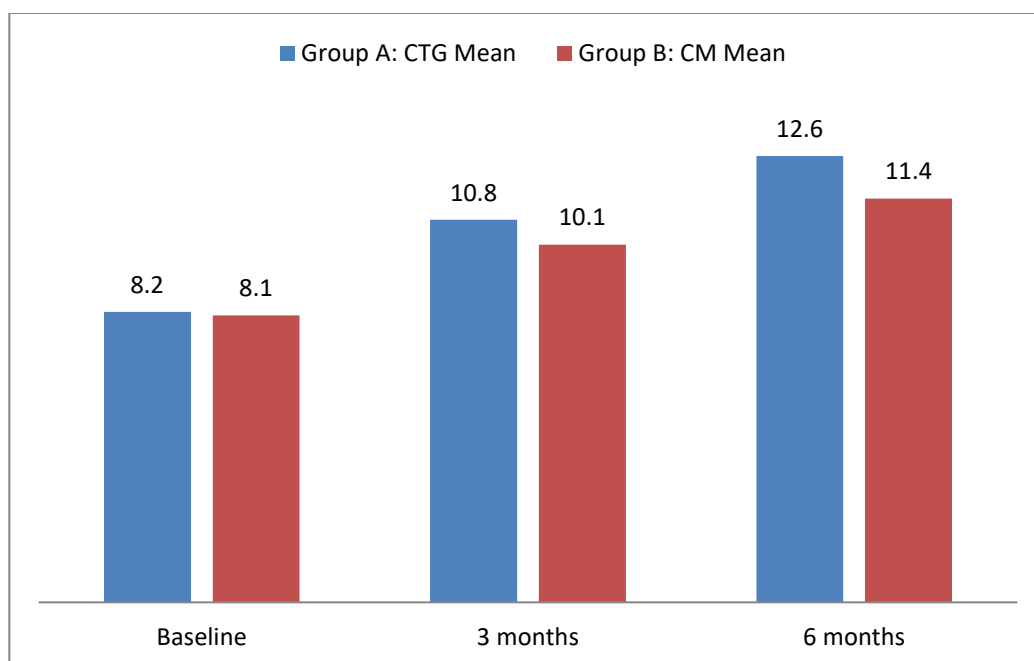


**Figure 10: Comparison of PES between the CTG and CM groups at baseline, 3 months, and 6 months**

Table 11 & Figure 11 present the comparison of postoperative pain between the CTG and CM groups using the VAS on postoperative days 1, 3, and 7. On the first postoperative day, the mean VAS pain score was  $6.20 \pm 1.15$  in Group A and  $4.10 \pm 1.05$  in Group B. This difference was highly statistically significant ( $t = 6.029$ ,  $p < 0.001$ ).

By postoperative day 3, pain levels had decreased in both groups; however, the CTG group continued to report significantly higher pain scores ( $4.30 \pm 1.10$ ) than the CM group ( $2.60 \pm 0.95$ ) ( $t = 5.230$ ,  $p < 0.001$ ).

On postoperative day 7, pain had further diminished in both groups, with mean VAS scores of  $1.80 \pm 0.75$  in Group A and  $0.90 \pm 0.60$  in Group B. The difference remained highly statistically significant ( $t = 4.191$ ,  $p < 0.001$ ).

Overall, postoperative pain progressively declined in both treatment groups during the first week after surgery. However, patients treated with the CM consistently experienced significantly lower pain levels than those who received connective tissue grafts. The increased discomfort observed in the CTG group is likely related to the additional surgical procedure required to harvest the palatal donor graft, whereas the CM avoids donor-site surgery and consequently reduces postoperative morbidity.

**Table 11: Comparison of postoperative pain assessed using VAS**

| Postoperative day | Group A: CTG Mean $\pm$ SD | Group B: CM Mean $\pm$ SD | t-value | p-value |
|-------------------|----------------------------|---------------------------|---------|---------|
| Day 1             | $6.20 \pm 1.15$            | $4.10 \pm 1.05$           | 6.029   | <0.001* |
| Day 3             | $4.30 \pm 1.10$            | $2.60 \pm 0.95$           | 5.230   | <0.001* |
| Day 7             | $1.80 \pm 0.75$            | $0.90 \pm 0.60$           | 4.191   | <0.001* |

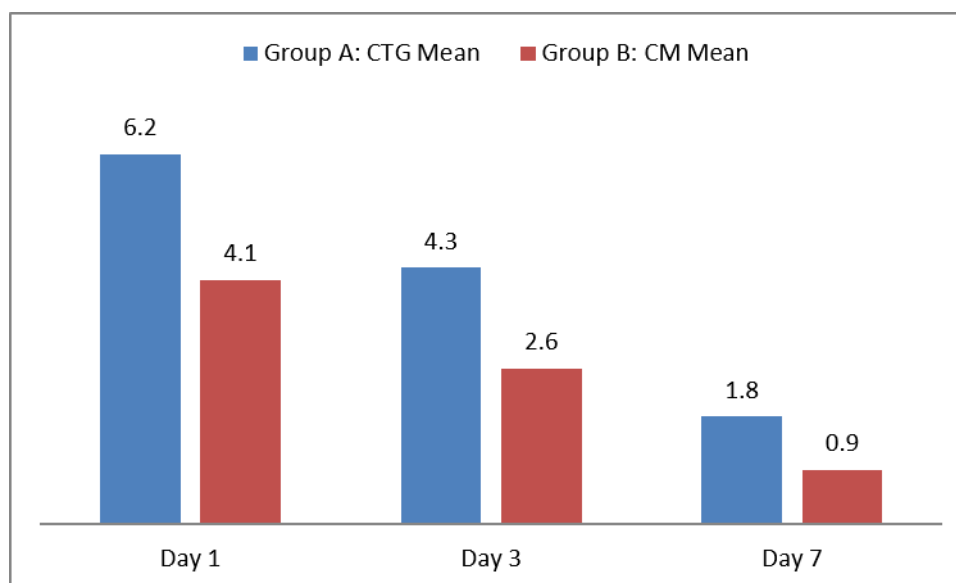


**Figure 11: Comparison of postoperative pain VAS scores between the CTG and CM groups on postoperative days 1, 3, and 7**

Table 12 & Figure 12 illustrate the distribution of patient satisfaction levels in the CTG and CM groups at the 6-month follow-up. In Group A (CTG), 9 patients (45.0%) reported being very satisfied, 8 patients (40.0%) were satisfied, and 3 patients (15.0%) expressed a neutral level of satisfaction. In Group B (CM), 14 patients (70.0%) were very satisfied and 6 patients (30.0%) were satisfied, while none reported a neutral response.

Overall, among the 40 study participants, 23 patients (57.5%) were very satisfied, 14 patients (35.0%) were satisfied, and 3 patients (7.5%)

reported a neutral level of satisfaction. The distribution of satisfaction scores differed significantly between the two treatment groups ( $p = 0.038$ ).

The CM group demonstrated a higher proportion of patients who were very satisfied with their treatment, indicating greater overall patient acceptance of this approach. This improved satisfaction may be attributed to the minimally invasive nature of the CM procedure, which avoids palatal donor-site harvesting, reduces postoperative discomfort, and enhances patient comfort during the recovery period.

**Table 12: Comparison of patient satisfaction at 6 months**

| Satisfaction category | Group A: CTG n (%) | Group B: CM n (%) | Total n (%) | p-value |
|-----------------------|--------------------|-------------------|-------------|---------|
| Very satisfied        | 9 (45.0)           | 14 (70.0)         | 23 (57.5)   | 0.038*  |
| Satisfied             | 8 (40.0)           | 6 (30.0)          | 14 (35.0)   |         |
| Neutral               | 3 (15.0)           | 0 (0.0)           | 3 (7.5)     |         |

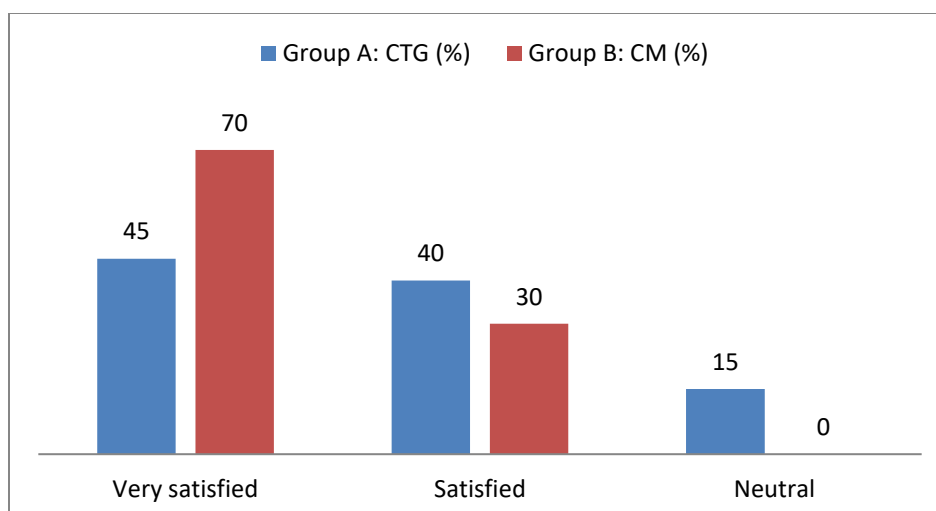


**Figure 12: Comparison of patient satisfaction levels between the CTG and CM groups at the 6-month follow-up**

Table 13 & Figure 13 provide an overall comparison of the principal clinical and patient-reported outcomes at the 6-month follow-up. The mean gain in peri-implant mucosal thickness was significantly higher in the CTG group ( $2.40 \pm 0.40$  mm) than in the CM group ( $1.80 \pm 0.30$  mm) ( $p = 0.002$ ), indicating that CTG was more effective in increasing peri-implant soft tissue thickness.

A similar trend was observed for the WKM, with a mean gain of  $2.25 \pm 0.48$  mm in Group A compared with  $1.73 \pm 0.44$  mm in Group B, demonstrating greater augmentation of keratinized peri-implant tissue with CTG. Esthetic outcomes also favored CTG, as reflected by a higher mean PES at 6 months ( $12.60 \pm 1.20$  versus  $11.40 \pm 1.30$ ).

In contrast, patient-centered outcomes were more favorable in the CM group. On the first postoperative day, the mean VAS pain score was

significantly lower in the CM group ( $4.10 \pm 1.05$ ) than in the CTG group ( $6.20 \pm 1.15$ ), indicating reduced postoperative discomfort. In addition, 70.0% of patients treated with the CM reported being very satisfied, compared with 45.0% of patients who underwent CTG.

Overall, the findings highlight a clear balance between clinical effectiveness and patient comfort. CTG achieved greater improvements in peri-implant mucosal thickness, WKM, and esthetic outcomes. Conversely, the CM offered advantages in terms of reduced postoperative pain and higher patient satisfaction. These results suggest that CTG may be the preferred option when maximizing soft tissue augmentation and esthetic outcomes is the primary treatment goal, whereas CM serves as an effective minimally invasive alternative for patients in whom reduced surgical morbidity and improved postoperative comfort are important clinical considerations.

**Table 13:** Summary of principal clinical outcomes at 6 months

| Outcome                     | Group A: CTG     | Group B: CM      | p-value | Inference    |
|-----------------------------|------------------|------------------|---------|--------------|
| Mucosal thickness gain (mm) | $2.40 \pm 0.40$  | $1.80 \pm 0.30$  | 0.002*  | CTG superior |
| WKM gain (mm)               | $2.25 \pm 0.48$  | $1.73 \pm 0.44$  | <0.001* | CTG superior |
| PES                         | $12.60 \pm 1.20$ | $11.40 \pm 1.30$ | 0.01*   | CTG superior |

|                       |             |             |         |                         |
|-----------------------|-------------|-------------|---------|-------------------------|
| Day-1 VAS pain        | 6.20 ± 1.15 | 4.10 ± 1.05 | <0.001* | CM superior for comfort |
| Very satisfied, n (%) | 9 (45.0)    | 14 (70.0)   | 0.038*  | CM favored              |

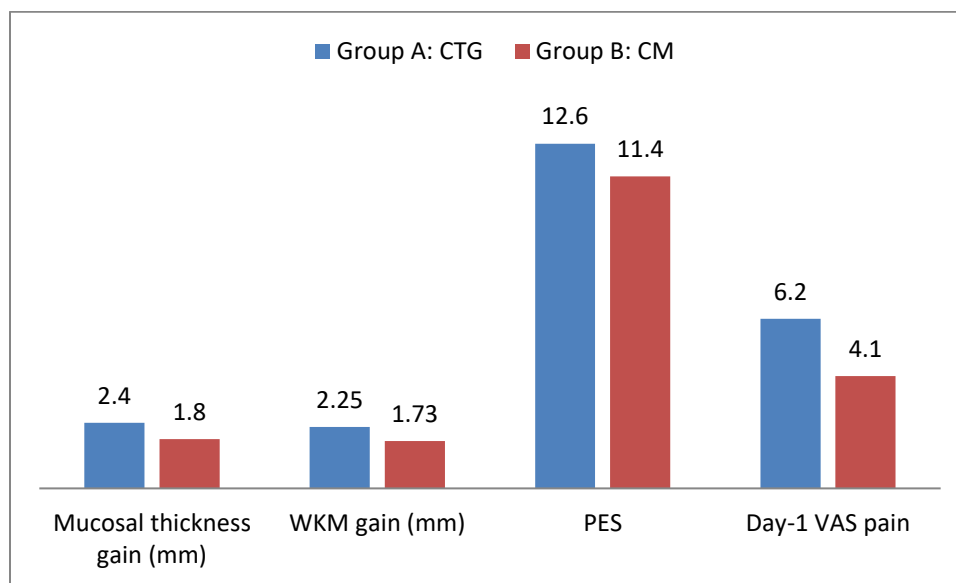


**Figure 13: Summary of key clinical and patient-reported outcomes at the 6-month follow-up in the CTG and CM groups**

### Discussion

The findings of the present study demonstrated that both CTGs and CMs were effective in improving peri-implant soft tissue parameters around dental implants. However, CTGs produced greater gains in mucosal thickness and KTW, whereas CMs were associated with reduced patient morbidity and favorable postoperative healing. These observations are consistent with the existing literature evaluating soft tissue augmentation procedures around implants.

Valles et al. (2022) [11], in a systematic review and meta-analysis, reported that soft tissue augmentation procedures significantly increased peri-implant mucosal thickness and contributed to improved peri-implant tissue stability. The authors concluded that autogenous CTGs generally achieved greater tissue thickening than substitute

materials, although both approaches yielded clinically beneficial outcomes. These findings support the present results, where CTGs demonstrated superior volumetric enhancement compared with CMs.

The effectiveness of peri-implant tissue augmentation observed in the present study may also be related to the importance of maintaining adequate hard- and soft-tissue dimensions around implants. Thoma et al. (2017) [12] emphasized that augmentation procedures performed simultaneously with implant placement improve peri-implant tissue architecture and long-term treatment outcomes. Although their review focused primarily on lateral bone augmentation, the authors highlighted the close relationship between underlying tissue support and peri-implant soft tissue stability, reinforcing the

rationale for augmentation procedures aimed at optimizing implant site development.

Esthetic outcomes are increasingly recognized as a critical determinant of implant treatment success, particularly in visible areas of the dentition. Fürhauser et al. (2005) [13] introduced the PES as a reliable method for assessing peri-implant soft tissue esthetics and demonstrated that harmonious soft tissue contours significantly influence overall implant appearance. In the present study, both treatment modalities contributed to improved peri-implant esthetics, with greater soft tissue volume achieved by CTGs potentially enhancing contour stability and tissue integration.

The importance of preserving and augmenting peri-implant soft tissues has also been highlighted by Jung et al. (2018) [14], who reported that maintenance of adequate ridge dimensions and peri-implant tissue volume is essential for achieving predictable esthetic outcomes. Their findings suggest that successful implant therapy requires not only osseointegration but also stable soft tissue architecture. The increased mucosal thickness observed following CTG therapy in the present study may therefore contribute to improved long-term esthetic and biological outcomes.

Patient-centered considerations are increasingly influencing the selection of augmentation materials. Although CTGs remain the gold standard, collagen-based substitutes offer the advantage of eliminating donor-site morbidity. Similar observations have been reported by Thoma et al. (2017), who demonstrated that xenogeneic CMs could provide clinically acceptable soft tissue augmentation while reducing surgical invasiveness and postoperative discomfort [12]. The favorable patient experience associated with CMs in the present study is in agreement with these findings and supports their use when minimizing patient morbidity is a primary treatment objective.

The significance of augmentation procedures for implant success has been recognized in broader implant rehabilitation research. Esposito et al. (2009) [15], in a Cochrane systematic review, concluded that augmentation procedures play a valuable role in creating adequate tissue dimensions for predictable implant placement and long-term function. Although focused largely on bone augmentation techniques, their conclusions underscore the importance of tissue enhancement strategies in optimizing implant outcomes, which is consistent with the improvements observed in the present investigation.

Overall, the present findings corroborate previous evidence indicating that both CTGs and CMs are effective treatment modalities for peri-implant soft tissue augmentation. CTGs continue to provide superior tissue volume enhancement and dimensional stability, whereas CMs offer a less invasive alternative with improved patient comfort. The choice between these approaches should therefore be guided by clinical requirements, esthetic demands, tissue deficiencies, and patient preferences.

### Limitations

The present study has several limitations that should be considered while interpreting the findings. The sample size was relatively small, which may have limited the ability to detect subtle differences between the treatment groups. The follow-up period of 6 months was insufficient to evaluate the long-term stability of peri-implant soft tissue augmentation and esthetic outcomes. As a single-center study, the findings may not be generalizable to broader patient populations. Variations in individual healing responses, gingival biotype, and oral hygiene practices may also have influenced the clinical outcomes. Furthermore, only clinical and esthetic parameters were evaluated, while histologic assessment of tissue integration and volumetric changes using three-dimensional imaging were not performed. Future multicenter randomized controlled trials with larger sample sizes, longer follow-up periods, and

advanced imaging techniques are recommended to validate these findings.

### Conclusion

Within the limitations of the present study, both CTGs and CMs were effective in enhancing peri-implant soft tissue quality by increasing mucosal thickness and the WKM while maintaining favorable peri-implant health. CTGs demonstrated superior soft tissue volume gain and esthetic outcomes, confirming their status as the gold

standard for peri-implant soft tissue augmentation. However, CMs provided satisfactory clinical results with significantly lower patient morbidity and improved postoperative comfort by eliminating the need for a donor site. Therefore, CMs represent a predictable and minimally invasive alternative for selected clinical situations, whereas CGs remains the preferred option when maximum soft tissue augmentation and esthetic enhancement are required.

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