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Original Article

Dentistry Section

Efficacy of T-PRF in Peri-implant Soft-tissue Augmentation and its Impact on Initial Marginal Bone Loss using the Bilayer Technique: A 6-month Prospective Clinical Trial

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ABSTRACT

Introduction: Adequate peri-implant soft-tissue thickness plays a critical role in stabilising marginal bone and improving long-term implant success. Limited evidence exists regarding the effect of Titanium-prepared Platelet-rich Fibrin (T-PRF) on peri-implant phenotype modification and early bone remodelling.

Aim: To assess the effect of bilayer T-PRF on peri-implant soft-tissues augmentation and initial Marginal Bone Levels (MBL).

Materials and Methods: This prospective, single-centre, single-arm clinical study included 15 systemically healthy patients reporting to Department of periodontics in GITAM Dental College and Hospital, Visakhapatnam, Andhra Pradesh, India with a single posterior edentulous site. The study period was May 2024 and November 2024. At implant placement, soft-tissue augmentation was performed using T-PRF membranes. Clinical parameters recorded at baseline, 3 and 6 months included Buccal Mucosal Thickness (BMT), Supracrestal Tissue Height (STH), Keratinised Mucosal Width (KMW) and Ridge Defect (RD), along with Plaque Index (PI) and Wound Healing Index (WHI) at one, three and six months postoperatively. MBL were assessed radiographically at baseline, three and six months. Patient-reported Outcome Measures (PROMs) were evaluated using a 100-mm Visual Analogue Scale (VAS) on postoperative days 1, 3, 7 and 14. Statistical analysis was performed using Statistical Packages of Social Sciences (SPSS) version 25.0 Descriptive statistics, Repeated measure Analysis of Variance (ANOVA), Banferroni Post-hoc test, Friedman test Wilcoxon sign rank test and Pearson's correlation test were used to analyse the data. $p<0.05$ was considered significant.

Results: The mean age of the study participants was 34±9.5 years Significant gains were observed in BMT (1.93 mm), STH (2.10 mm), and KMW (0.43 mm) from baseline to six months ($p<0.05$). Mean MBL at six months was 0.55 mm mesially and 0.46 mm distally. BMT showed a strong negative correlation with MBL (r=-0.72), STH a moderate correlation (r=-0.58), KMW a weak correlation (r=-0.32), and RD a very weak, non significant correlation (r=-0.14). PROM scores progressively decreased and approached zero by day 14.

Conclusion: The T-PRF effectively enhanced peri-implant soft-tissue thickness and was associated with minimal early Marginal Bone Loss (MBL). Its sustained growth-factor release and favourable biological behaviour support its use as a biomaterial for peri-implant soft-tissue augmentation.

Keywords: Dental implants, Peri-implant phenotype, Osseointegration, Keratinised tissue, Growth-factors, Platelet concentrate, Ridge defect, Wound healing, Outcome measures, Titanium-prepared Platelet-rich Fibrin

INTRODUCTION

Dental implants are a well-established treatment option for replacing missing teeth, offering long lasting functional and aesthetic advantages. Consequently, maintaining healthy peri-implant tissues is essential for the long-term success and stability of implants [1]. The presence of ideal peri-implant phenotype (BMT >2 mm, STH>3 mm, KMW >2 mm), has several benefits such as short-term (early) healing phase, re-establishment of the convex ridge contour. In the long-run, peri-implant health is indicated by reduced probing depths, decreased plaque and bleeding scores, as well as stable MBLs or minimal marginal bone changes. Furthermore, mucosal thickness augmentation can mask the tissue discolouration caused by metallic abutments when the peri-implant mucosal thickness is thin, thereby improving the aesthetic outcome. In addition, soft-tissue augmentation also favours the stability of the mucosal margin [2].

The initial bone modelling around implants within the first year after insertion presents a challenging condition for the clinicians. A horizontal and vertical bone remodelling of 0.7 to 3 mm is most commonly observed in the first year of implant placement. The two predominant strategies employed are platform switching and peri-implant soft-tissue augmentation, of which peri-implant soft-tissue augmentation leads to more consistent and stable treatment outcomes [3]. Various techniques and materials have been used to thicken the peri-implant mucosa which includes, Connective Tissue Grafts (CTG), Platelet Concentrates (PC), and xenogenic collagen matrix [4].

Although CTG has been considered as the gold standard for soft-tissue augmentation, the limited supply of donor tissue, second surgical site and the postoperative pain that results from injury to the palatal vessels and nerves can necessitate the use of alternative methods [4]. PCs became viable alternatives in recent times. The drawbacks of the first-generation PCs lead the researchers to investigate for a better biomaterial with broad clinical applications. T-PRF, a third-generation PC, was introduced by Mustafa Tunali in 2013. It is prepared using grade IV titanium tubes which have passivated titanium dioxide, enhancing its biocompatibility. T-PRF features a denser, more organised fibrin matrix with higher cellular content, increased growth factor release, and a reduced Receptor Activator of Nuclear factor-κβ Ligand (RANKL)/OPG ratio [5,6]. Its natural fibrin structure protects growth factors from proteolysis, hereby extending their resorption time [7]. This matrix serves as

a scaffold for gingival fibroblast and osteoblast proliferation and differentiation, as well as new blood vessel formation [8]. Using two T-PRF membranes improves space maintenance, inhibits epithelial cell migration, and encourages Periodontal Ligament (PDL) cell migration, thereby supporting periodontal regeneration [8,9]. However, the most effective treatment may not always be the best option for every individual. Instead, the preferred approach is often the one that aligns best with both positive clinical outcomes and the patient's personal values and expectations. As a result, PROMs are increasingly essential in treatment planning [2].

Although previous studies have evaluated T-PRF for soft-tissue augmentation [3,4,9,10] evidence remains limited regarding its bilayer application and its combined effect on peri-implant soft-tissue phenotype, early marginal bone behaviour and PROMs. This prospective clinical trial addresses these gaps by simultaneously assessing soft-tissue parameters, initial bone remodelling and patient-reported outcomes following T-PRF augmentation.

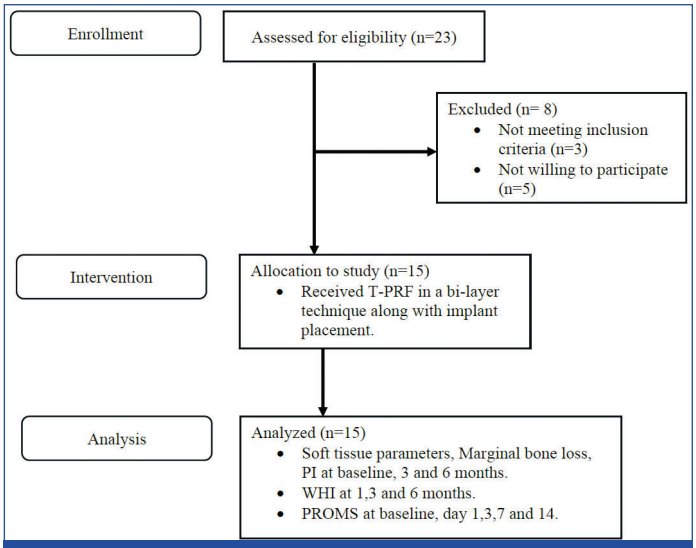
Therefore, present study aimed to evaluate the influence of bilayer T-PRF augmentation during implant placement on peri-implant soft-tissue augmentation, early marginal bone changes, and patient-reported outcomes over a 6-month period.

MATERIALS AND METHODS

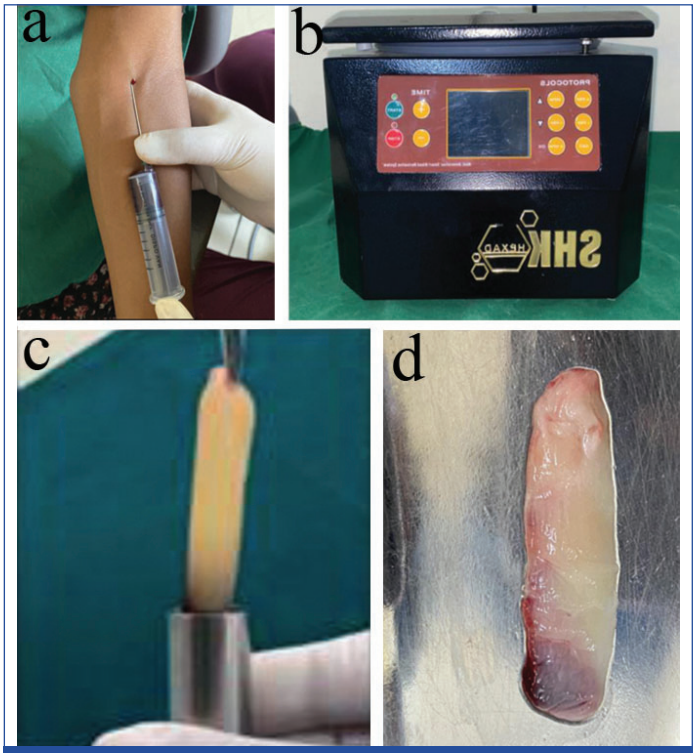
The present prospective, single-centre, single-arm clinical study was conducted in the Department of Periodontology, GITAM Dental College & Hospital, Visakhapatnam, Andhra Pradesh, India, between May 2024 and November 2024. The study adhered to the ethical principles of the Declaration of Helsinki (2013 revision) and received approval from the Institutional Ethics Committee (IEC Protocol Number: 46086060523). All clinical parameters were recorded by a single examiner who was blinded to the treatment protocol, study objectives, and follow-up interval assignments to minimise measurement bias. Convenience sampling was used for participant recruitment. Written informed consent was obtained from all participants prior to enrollment in the study.

Sample size calculation: Sample size was calculated using G*Power 3.1.9.4, adopting an effect size of 0.99 derived from previous soft-tissue augmentation studies [11], α=0.05 and 1-β=0.86, yielding a minimum of 15 subjects.

Inclusion and Exclusion criteria: Patients aged 18 years and above with good oral and systemic health, a single posterior edentulous site with adjacent natural teeth without periodontal disease, and a thin gingival phenotype were included. Exclusion criteria comprised a history of head or neck cancer treatment, use of medications affecting bone metabolism (e.g., bisphosphonates), pregnancy or lactation, smoking, substance abuse, and non compliance. The study layout has been depicted in [Table/Fig-1].



[Table/Fig-1]: Flowchart illustrating the process of enrollment, treatment and follow-up.



[Table/Fig-2]: a) 10 mL of blood withdrawn from antecubital vein; b)The tubes were immediately centrifuged at 2700 rpm for 12 min; c) Titanium tubes were used for preparation of PRF and T-PRF clots were removed from the tubes via sterile tweezers; d) Compression was done to form membrane.

Study Procedure

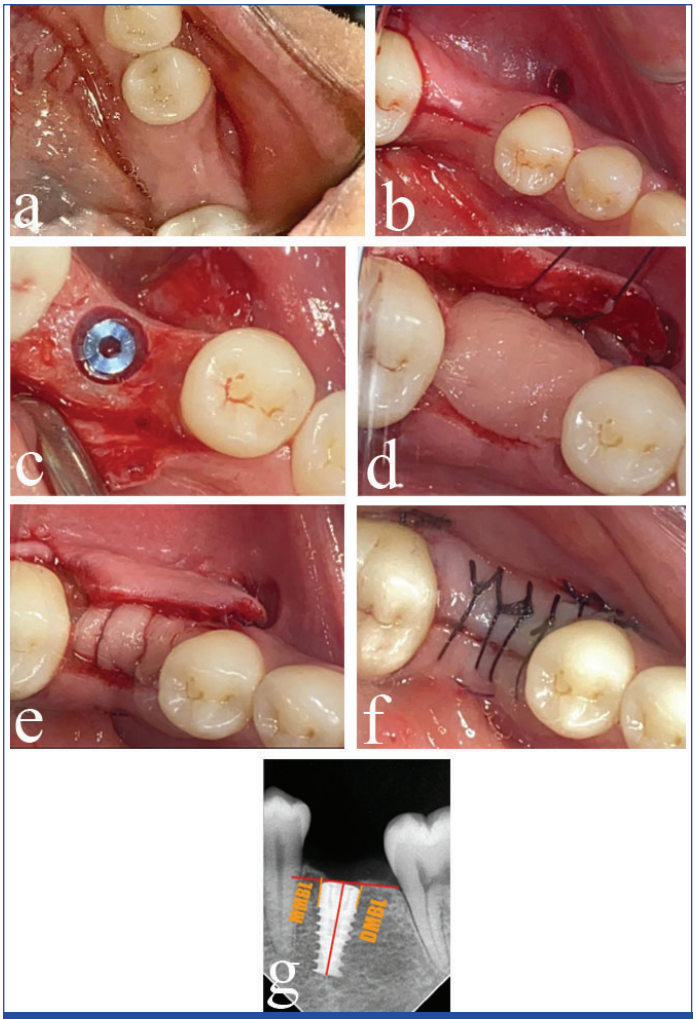
Pre-surgical phase: All participants underwent complete oral prophylaxis one week before surgery and were instructed on maintaining good oral hygiene throughout the study period.

T-PRF preparation: T-PRF was prepared according to the protocol described by Tunalı M et al., 2013. T-PRF was prepared by drawing 10 mL of venous blood and transferring it to grade IV titanium tubes (Intra-Spin, USA). A control tube with sterile water ensured balanced centrifugation. Centrifugation was performed at 2700 rpm for 12 minutes, and the resulting clot was then placed in a PRF box to obtain uniform membranes. Fibrin clot obtained was separated and gently compressed in a PRF box to form membrane-like structures, which were kept sterile until surgical placement [Table/Fig-2] [5].

Surgical procedure: Local anaesthesia (2% lignocaine with 1:80,000 adrenaline) was administered, followed by a mid-crestal incision with minimal vertical releases. A full-thickness mucoperiosteal flap was elevated. Implants of the Bioline brand SLA-modified were used (Bioline Dental Implants GmbH, Germany). The implants varied in diameter (3.75 mm and 4.2 mm) and in length (10 mm and 11.5 mm). Osteotomy was prepared according to the Bioline implant manufacturer's protocol, and the implants were inserted with a final insertion torque ≥35 Ncm and placed at crestal level.

The T-PRF membranes were then positioned using the bilayer technique described by Lima VC et al., [8] and Soni R et al., [9], Hehn J et al., [3] wherein one membrane was placed beneath the buccal flap and another across the crest to enhance space maintenance and epithelial exclusion. The membranes were stabilised using periosteal suturing with 4-0 Vicryl sutures. Flaps were approximated for tension-free primary closure with 4-0 Advasyl sutures [Table/Fig-3].

Clinical parameters: The clinical parameters BMT, STH, RD, MBL, PI, WHI, PROM were recorded. All clinical parameters were recorded by a single calibrated examiner (intraexaminer reliability k=0.86), who was blinded to the treatment protocol, study objectives, and follow-up interval assignments to minimise measurement bias.



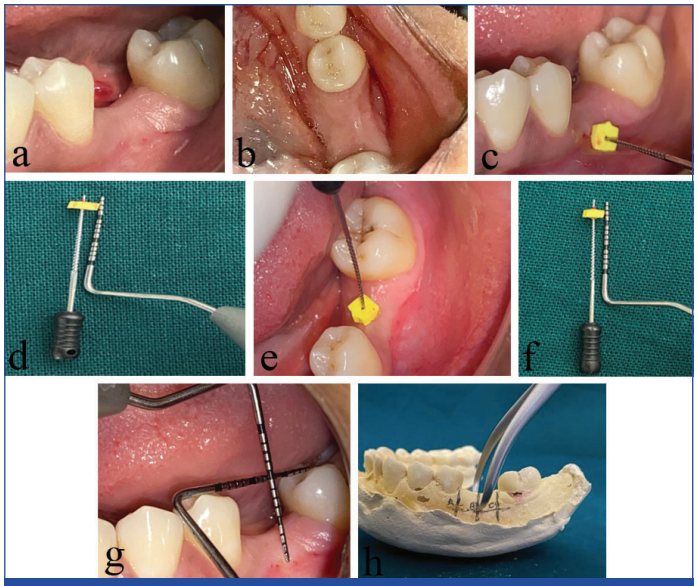
[Table/Fig-3]: a) Occlusal aspect of the edentulous ridge; b) Crestal incision; c) Occlusal aspect of the ridge after implant placement; d) Insertion of T-PRF membranes in a double-layered technique for tissue augmentation; e) Periosteal suturing of T-PRF membranes; f) Tension free flap approximation using 4-0 Vicryl Advasyl sutures; g) Radiograph at time of implant placement representing Mesial Marginal Bone Level (MMBL) and Distal Marginal Bone Level (DMBL).

A. Soft-tissue parameters

1. **Buccal Mucosal Thickness (BMT):** BMT was measured 3 mm apical to the mucosal margin using an ISO #20 stainless steel endodontic spreader with a silicone stopper (Mani Inc., Japan), following the method described by Januário AL et al., 2008 [12].
2. **Supracrestal Tissue Height (STH):** STH was recorded as the distance from the mucosal margin to the crestal bone using a University North Carolina (UNC)-15 probe (Hu-Friedy, USA) probe, based on the methodology given by Salama H et al., 1998 [13].
3. **Keratinised Mucosa Width (KMW):** KMW was measured as the distance from the mucosal margin to the mucogingival junction using a University North Carolina (UNC)-15 probe (Hu-Friedy, USA) probe, according to Fischer KR et al., 2018 [14].
4. **Ridge Defect (RD):** The RD (buccolingual width) was measured on diagnostic casts using digital calipers following the cast-based ridge-width measurement method of Januário AL et al., and Lundgren D et al., [Table/Fig-4] [12,15].

B. Hard-tissue parameter

Marginal Bone Levels (MBL): Standardised Intraoral Periapical Radiographs (IOPAs) were obtained using Rinn XCP holders. MBL was measured mesially and distally as the distance from the implant shoulder to the first bone-to-implant contact using ImageJ software (Version 1.54, National Institutes of Health, Maryland, USA) [16]. Radiographic measurements were calibrated using implant thread pitch to eliminate magnification.



[Table/Fig-4]: Presurgical parameters measurement: a) Buccal view of edentulous ridge; b) occlusal view of edentulous ridge; c & d) BMT measurement; e & f) STH measurement; g) KTW measurement; h) RD measurement on a cast.

Repeated evaluations showed an intrarater measurement error of 0.31±0.19 mm (standard deviation) and an intraclass correlation coefficient of 0.99 (95% confidence interval: 0.99-1.00).

Clinical Indices

- **Plaque Index (PI):** Plaque accumulation was assessed using the Silness and Löe PI (1964), which scores each tooth surface on a scale from 0 to 3. A score of 0 indicates the absence of plaque, while a score 3 signifies an abundance of plaque on the tooth surface and within the gingival margin [17].
- **Wound Healing Index (WHI):** Soft-tissue healing was evaluated using the Landry, Turnbull and Howley WHI (1988) at 1, 3, and 6 months, scored from 1 (very poor) to 5 (excellent) [18].
- **Patient-reported Outcome Measures (PROMs):** PROMs included pain, swelling, and discomfort assessed using a 100-mm VAS on days 1, 3, 7 and 14, following standard postoperative assessment protocols [19].
- **Postsurgical phase:** Postoperative instructions included amoxicillin were prescribed (500 mg, 8 hour) for seven days and antimicrobial rinse (0.12% chlorhexidine, twice daily for 2 weeks) for plaque control along with non mechanical plaque control for seven days weeks. The sutures were removed after seven to 10 days.

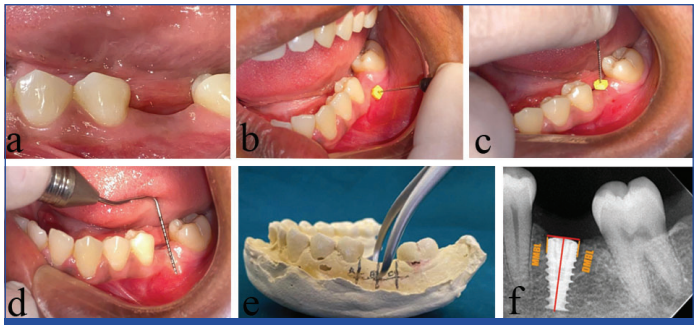
The BMT, STH, KTW, RD, full mouth PI, and MBL were assessed at baseline and re-evaluated at 3 and 6 months [Table/Fig-5,6]. WHI was recorded at 1, 3, and 6 months postoperatively. PROMs using the VAS were collected at baseline and on days 1, 3, 7, and 14.

STATISTICAL ANALYSIS

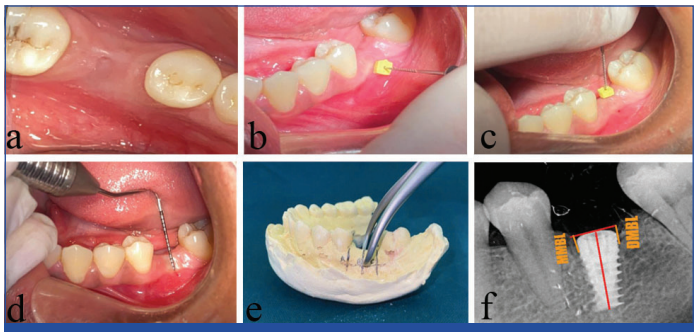
The SPSS version 25.0 was used for all analyses. Data normality was evaluated using the Shapiro-Wilk test. Repeated-measures ANOVA with Bonferroni correction was used for normally distributed variables, while non parametric variables were analysed using the Friedman and Wilcoxon signed-rank tests. Effect sizes (η^2 for ANOVA, r for non parametric tests) were calculated. Pearson's correlation assessed associations between soft-tissue parameters and MBL. Statistical significance was set at $p<0.05$.

RESULTS

A total of 23 individuals were screened, of whom 15 eligible participants were enrolled in the study (n=15), comprising six males and nine females, with an age range of 25-58 years (mean age: 34±9.5 years). Each participant received a single implant



[Table/Fig-5]: Three months postsurgical parameters measurement: a) clinical view of surgical area; b) BMT measurement; c) STH measurement, d) KTW measurement; e) RD measurement on a cast; f) Radiograph representing MMBL and DMBL three months postsurgical.



[Table/Fig-6]: Six months postsurgical parameters measurement: a) clinical view of surgical area; b) Buccal Mucosal Thickness (BMT) measurement; c) STH measurement; d) KMW measurement; e) RD measurement on a cast; f) Radiograph representing MMBL and DMBL six months postsurgical.

with simultaneous soft-tissue augmentation using T-PRF and completed the entire 6-month follow-up period. No intraoperative or postoperative complications or adverse events were observed.

Soft-Tissue and Hard-Tissue outcomes

The mean BMT values were 2.53±0.85, 4.33±1.06, and 4.47±0.85 at baseline, three months, and six months, respectively. The corresponding STH values were 2.57±0.45, 4.53±0.89, and 4.67±0.94; KMW values were 3.30±0.65, 3.73±0.82, and 3.73±0.82; and RD values were 7.06±0.95, 8.09±1.20, and 8.09±1.20. Repeated-measures ANOVA revealed statistically significant changes across time intervals for all parameters (p<0.001***) [Table/Fig-7].

Post-hoc Analysis

Bonferroni-adjusted Post-hoc tests confirmed significant improvement from baseline to three months and baseline to six months for BMT, STH, and KMW. RD demonstrated improvement over time but no significant change between three and six months [Table/Fig-8].

Plaque Index (PI), Healing Index, and PROMs

The mean PI decreased significantly from 0.89±0.55 at baseline to 0.29±0.35 at six months (p<0.001). The Wound-Healing Index (WHI) demonstrated progressive improvement, increasing from 3.80±1.01 at 1 month 4.53±1.06 at six months (p=0.043). PROM (VAS scores) also showed a marked decline in postoperative discomfort, reducing from 4.00±1.51 on Day 0 to 2.13±1.35 on Day 1 and 0.80±0.86 on Day 3, reaching 0.00 by Days 7 and 14 (p<0.001). These findings collectively indicate significant improvements in plaque control, wound healing, and patient comfort across the evaluation period [Table/Fig-9].

Correlation Analysis

Pearson's correlation analysis demonstrated a strong negative association between BMT and MBL (r=-0.72, p<0.001***), and a moderate negative association between STH and MBL (r=-0.58, p=0.012). KMW also showed a weak but statistically significant correlation with MBL (r=-0.32, p=0.041*). RD showed only a very weak, non significant correlation with MBL (r=-0.14, p=0.112) [Table/Fig-10].

Outcome	Time interval	Mean±SD (mm)		p-value
BMT	Baseline	2.53±0.85		p<0.001**
	3 months	4.33±1.06		
	6 months	4.47±0.85		
STH	Baseline	2.57±0.46		p<0.001**
	3 months	4.53±0.89		
	6 months	4.67±0.94		
KMW	Baseline	3.30±0.65		p=0.003
	3 months	3.73±0.82		
	6 months	3.73±0.82		
RD	Baseline	7.06±0.96		p<0.001**
	3 months	8.09±1.20		
	6 months	8.09±1.20		
MBL	Baseline (M/D)	0		p<0.001**
	3 months (M/D)	0.48 / 0.39	0.34 / 0.21	
	6 months (M/D)	0.56 / 0.46	0.37 / 0.20	

[Table/Fig-7]: Comparison of soft- and hard-tissue parameters across baseline, three months, six months (repeated-measures ANOVA) (n=15).
BMT: Buccal mucosal thickness; STH: Supracrestal tissue height; KMW: Keratinised mucosa width; MB: Marginal bone levels; *p≤0.05 (significant), **p≤0.01 (highly significant), ***p≤0.001 (very highly significant)

Outcome	Time (I)	Time (J)	Mean Diff (I-J)	p-value
BMT	Baseline	3 months	-1.80	p<0.001**
	Baseline	6 months	-1.93	p<0.001**
STH	Baseline	3 months	-1.97	p<0.001**
	Baseline	6 months	-2.10	p<0.001**
KMW	Baseline	3 months	-0.43	p=0.008
	Baseline	6 months	-0.43	p=0.008
RD	Baseline	3 months	-1.03	p=0.170
	Baseline	6 months	-1.03	p=0.170
MBL (Mesial)	Baseline	6 months	-0.56	p<0.001**
MBL (Distal)	Baseline	6 months	-0.46	p<0.001**

[Table/Fig-8]: Pair-wise post-hoc comparison using Bonferroni-adjusted tests following repeated-measures ANOVA. (n=15).
BMT: Buccal mucosal thickness; STH: Supracrestal tissue height; KMW: Keratinised mucosa width; RD: Ridge defect; MBL: Marginal bone loss; M: Mesial; D: Distal; *p≤0.05 (significant), **p≤0.01 (highly significant), ***p≤0.001 (very highly significant)

Outcome	Time Interval	Mean±SD	p-value
PI	Baseline	0.89±0.55	p<0.001**
	3 months	0.27±0.30	
	6 months	0.29±0.35	
WHI	1 month	3.80±1.01	p=0.043
	3 months	3.93±1.27	
	6 months	4.53±1.06	
PROMS	Day 0	4.00±1.51	p<0.001**
	Day 1	2.13±1.35	
	Day 3	0.80±0.86	
	Day 7	0.00±0.00	
	Day 14	0.00±0.00	

[Table/Fig-9]: PI, WHI, and PROMS Scores across baseline, three and six-months time intervals (Friedman+Wilcoxon Signed-Rank Tests) (n=15).
Analysis of plaque accumulation, wound healing, and patient-reported pain over time using Friedman test with Wilcoxon signed-rank Post-hoc comparisons; PI: Plaque index; WHI: Wound healing index; VAS: Visual analogue scale. Significance: *p≤0.05 (significant), **p≤0.01 (highly significant), ***p≤0.001 (very highly significant)

Parameters	r-value	p-value	Interpretation
BMT	-0.72	p<0.001**	Strong negative correlation
STH	-0.58	p=0.012	Moderate negative correlation
KMW	-0.32	p=0.041*	Weak negative correlation
RD	-0.14	p=0.112	Very weak, non significant

[Table/Fig-10]: Pearson's correlation between soft-tissue parameters and MBL (n=15).
Significance: *p≤0.05 (significant), **p≤0.01 (highly significant), ***p≤0.001 (very highly significant)

DISCUSSION

The present prospective clinical study therefore aimed to assess the ability of T-PRF to enhance peri-implant mucosal dimensions using a bilayer technique and to evaluate its effect on early marginal bone remodelling and patient-reported outcomes. The results demonstrated significant improvements in BMT (mean gain 1.93 mm; p<0.001), STH (mean gain 2.10 mm; p<0.001), and keratinised mucosa width (mean gain 0.43 mm; p=0.008), accompanied by minimal early MBL (0.55 mm mesial, 0.46 mm distal) and favourable PROMs, confirming the biological potential of T-PRF in soft-tissue augmentation.

Thin peri-implant mucosa remains a well-documented risk factor for recession and early crestal bone remodelling, as demonstrated by Berglundh T and Lindhe J, Linkevicius T and Puisys A, Puisys A and Linkevicius T and Lai HC et al., [20-23]. Several comparative clinical studies have shown that soft-tissue augmentation procedures yield mean mucosal thickness gains of 1.5-2.5 mm (p<0.05) and contribute to improved soft-tissue stability around implants [24,25]. These values closely correspond with the present study's outcomes (BMT gain 1.93 mm), reinforcing the biological efficacy of soft-tissue augmentation adjunctive to implant placement. Evidence continues to support soft-tissue augmentation as a proactive measure, with randomised trials reporting significantly less marginal bone remodelling when peri-implant mucosal thickness exceeds 2 mm [21,26]. Studies comparing simultaneous and staged soft-tissue augmentation report no significant difference in final tissue thickness achieved (mean range: 1.4-2.2 mm; p> 0.05), supporting the combined approach used in present study [26,27].

The bilayer placement of T-PRF used in present study one membrane beneath the flap and another over the crest is consistent with the approach described by Hehn J et al., Soni R et al., Polanco NLDH et al., improving space maintenance and enhancing tissue stability [3,9,10].

Soft-tissue Outcomes

The present study demonstrated statistically significant improvements in peri-implant soft-tissue dimensions, with mean gains of 1.93 mm in BMT, 2.1 mm in STH, and 0.43 mm in KMW. These outcomes can be attributed to the biological properties of T-PRF, which forms a dense, well-organised, highly cross-linked fibrin matrix with uniform platelet-leukocyte distribution. This architecture provides superior mechanical stability, slower degradation, and prolonged biological activity compared with conventional PRF preparations. The leukocyte-rich component enhances antimicrobial defence, debris clearance, and mesenchymal cell recruitment, while platelets release signalling molecules essential for early tissue repair. T-PRF further supports healing through the sustained release of growth factors—including VEGF, PDGF, TGF-β, IGF, FGF, and HGF- which promote angiogenesis, collagen formation, and overall soft-tissue regeneration. These mechanisms collectively explain the soft-tissue improvements observed and align with the findings of Ustaoglu G et al., (2020) and Gumus KC et al., who reported similar enhancements due to platelet-derived growth factors within the fibrin scaffold [4,28].

Additionally, the histoconductive properties of T-PRF likely contributed to the increased soft-tissue thickness. The reduction in RD (mean RD gain: 1.03 mm) parallels the results reported by Lima VC et al., (2020) further supporting the clinical efficacy of T-PRF as a soft-tissue augmentation material around implants [8].

Marginal Bone Loss (MBL)

Radiographic evaluation showed a statistically significant mean MBL of 0.55 mm mesially and 0.46 mm distally over six months-well within the acceptable range of 1-1.5 mm for the first year post-implant placement. This bone stability is likely due to T-PRF's slow resorption, dense fibrin structure, and sustained release of growth factors, which help lower the RANKL-OPG ratio. Increased osteoprotegerin levels stimulate osteoblast activity, supporting their migration, proliferation, and differentiation for new bone formation, while reduced RANKL limits osteoclastic bone resorption, promoting bone regeneration. These findings are consistent with those reported by Ustaoglu G et al., (2020), Oza R et al., (2021), and Badrasawi IY et al., (2024), Ravi S and Santhanakrishnan M [4,29-31].

Correlation analysis in the present study demonstrated a strong inverse correlation between BMT and MBL (r=-0.72; p<0.001), a moderate inverse correlation between STH and MBL (r=-0.58; p=0.012), and a weak but significant inverse correlation between KMW and MBL (r=-0.32; p=0.041). RD showed a very weak, non significant correlation (r=-0.14; p=0.112). It is hypothesised that crestal bone loss occurs when mucosal thickness is insufficient, as demonstrated by Berglundh T and Lindhe J (1996), who showed that adequate soft-tissue is necessary to establish a biological width around implants. Thin crestal mucosa leads to increased MBL as bone resorption occurs to create space for connective tissue and junctional epithelium [20]. This was supported by Berglundh T and Lindhe J, Linkevicius T and Puisys A Puisys A and Linkevicius T and Lai HC et al., [20-23], however Abrahamsson I et al., Bouri A et al. Lindhe J et al., who have reported that thicker tissues lead to less MBL around implants [32-34]. On the contrary, Chung DM et al., reported that narrow width of KM had little to no impact on alveolar bone level [35]. Crespi R et al., also supported that the presence of mid-buccal KM was not a critical factor in the maintenance of interproximal bone level immediately surrounding the loaded fresh socket implants [36].

Plaque and Wound Healing Indices

PI scores in this study showed a significant reduction, likely attributable to the increased soft-tissue thickness and improved hygiene accessibility. Evidence indicates that sites with <2 mm of keratinised mucosa exhibit greater plaque accumulation and increased pro inflammatory mediator expression. This aligns with findings by Bouri A et al., Chung DM et al., and Boynuegri D et al., [33,35,37]. However, contrasting studies by Wennström JL, Kim BS et al., Park JC et al., and Freese J, et al., suggest that when patients maintain good oral hygiene, plaque accumulation may remain low regardless of KM width [38-41]. These differing results indicate that while adequate KMW enhances hygiene and tissue health, patient compliance remains an important modifying factor.

Landry's WHI scores improved markedly over the six-month period. Previous studies by Hehn J et al., Ustaoglu G et al., Ercan E and describe T-PRF as a "healing biomaterial" owing to its immunomodulatory activity, particularly its interaction with neutrophils that promotes the release of antimicrobial agents such as lysozyme, myeloperoxidase, cathelicidins, and α-defensins. In addition, the early and sustained release of growth factors from T-PRF enhances angiogenesis, collagen synthesis, and overall tissue regeneration. These mechanisms align with the improved peri-implant soft-tissue healing observed in the present study [3,16,42].

Patient Reported Outcome Measures (PROMs)

Patients' perceptions of treatment success do not always mirror objective clinical outcomes; therefore, incorporating PROMs is crucial. Although standardised reporting methods are limited, VAS remains widely used for evaluating early postoperative discomfort. In this study, pain, discomfort, swelling were assessed on days 1, 3, 7 and 14. The favourable PROMs observed may be attributed to the controlled release of growth factors and the antibacterial,

anti-inflammatory, and analgesic properties of T-PRF [43]. Overall, these findings indicate a positive short-term patient experience and support the clinical acceptability of the procedure.

Rationale for Short-Term Evaluation

A six-month follow-up period was selected, as soft-tissue outcomes may be influenced by prosthetic restoration placement and individual variations in oral hygiene practices. Moreover, evidence from a recent systematic review and randomised controlled trial indicates that peri-implant soft-tissue stability is typically achieved within three months post-surgery [2,26].

Clinical Implications

The T-PRF shows clear potential as a minimally invasive soft-tissue augmentation technique during implant placement. Improvements in BMT, STH, and KMW, along with limited early MBL, indicate enhanced peri-implant soft-tissue stability and reduced crestal remodelling. As an autologous material that avoids a donor site, T-PRF provides a more comfortable alternative to CTGs and demonstrates favourable PROMs with predictable healing. These findings support the use of T-PRF in routine peri-implant soft-tissue management to improve both biological and clinical outcomes.

Limitation(s)

The present study is limited by a small sample size (n=15), short follow-up period, use of two-dimensional radiographs for MBL evaluation, absence of vitamin D status assessment, and lack of a parallel control group such as SCTG.

CONCLUSION(S)

The T-PRF in combination with simultaneous implant placement enhances peri-implant soft-tissue parameters both biologically and clinically while also resulting in minimal initial MBL and favourable PROMs over a 6-month follow-up period. Larger studies with extended follow-up and histological evaluation are needed to confirm long-term peri-implant tissue stability.

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