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Original Research Article

Correlation Between Esthetic Outcomes and Peri-Implant Bone Parameters Following Immediate Implant Placement in Defective Fresh Extraction Sockets Using Vestibular Socket Therapy with or Without Injectable Platelet-Rich Fibrin

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Abstract: ***Objective:*** This study aimed to investigate the relationship between peri-implant esthetic outcomes and radiographically assessed peri-implant bone parameters following immediate implant placement in defective fresh extraction sockets managed using vestibular socket therapy (VST), with or without adjunctive injectable platelet-rich fibrin (i-PRF). ***Materials and Methods:*** Twelve patients requiring immediate implant placement in the maxillary esthetic zone were enrolled and randomly allocated into two equal groups. Group I received immediate implants using VST alone, while Group II received VST combined with i-PRF. Esthetic outcomes were evaluated using the Pink Esthetic Score (PES) at 6 and 9 months. Peri-implant bone parameters, including cervical facial bone thickness and the vertical distance from the implant platform to the crestal bone level, were assessed using cone-beam computed tomography at baseline, 6 months, and 9 months. Intra-group and inter-group comparisons were performed using appropriate parametric and non-parametric tests. Correlation analysis between PES and peri-implant bone parameters was conducted using Spearman's rank correlation coefficient. ***Results:*** Inter-group analysis revealed no statistically significant differences in PES or peri-implant bone parameters at any evaluation period ($P > 0.05$). Both groups demonstrated significant intra-group improvement in PES and peri-implant bone dimensions over time ($P < 0.05$). Correlation analysis showed weak to moderate positive correlations between PES and peri-implant bone parameters at both 6 and 9 months; however, these associations were not statistically significant in either group ($P > 0.05$). ***Conclusion:*** The findings suggest that esthetic improvements following immediate implant placement using VST may occur independently of quantitative peri-implant bone dimensional changes, regardless of the adjunctive use of i-PRF.

Keywords: Immediate implant placement; Vestibular socket therapy; Injectable platelet-rich fibrin; Pink Esthetic Score; Cone-beam computed tomography; Peri-implant bone parameters; Esthetic outcomes.

INTRODUCTION

Immediate implant placement in fresh extraction sockets has become a well-established treatment modality, particularly in the esthetic zone, owing to its potential to reduce treatment time and preserve peri-implant tissues. However, dimensional alterations of the alveolar ridge following tooth extraction remain unavoidable, especially at the facial aspect, and may negatively influence the stability of both hard and soft tissues around immediately placed implants (1,2). These post-extraction changes are particularly relevant in the anterior maxilla, where minor tissue alterations may compromise esthetic outcomes (3).

Previous studies have demonstrated that the thickness and integrity of the facial bone wall play a critical role in maintaining peri-implant soft tissue

architecture. A thin or deficient facial bone has been associated with an increased risk of gingival recession and unfavorable esthetic outcomes following immediate implant placement (4,5). Consequently, several surgical approaches have been proposed to preserve or reconstruct the facial bone wall to optimize esthetic predictability. Vestibular socket therapy (VST) has been introduced as a biologically driven, minimally invasive technique aimed at preserving the facial bone wall via remote vestibular access and a subperiosteal tunnel, allowing placement and stabilization of a slowly resorbable xenograft lamina without disturbing the marginal soft tissues (6,7). This approach seeks to maintain the peri-implant complex tissue framework, which may serve as a prerequisite for stable soft tissue esthetics.

In parallel, platelet concentrates have gained increasing attention as adjunctive biologic modifiers in implant and periodontal therapy. Injectable platelet-rich fibrin (i-PRF), prepared using the low-speed centrifugation concept, has been shown to enhance angiogenesis, fibroblast proliferation, and soft tissue healing, potentially contributing to improved peri-implant esthetic outcomes without necessarily inducing marked changes in bone dimensions (8–10). While both peri-implant bone stability and soft tissue quality are considered essential determinants of esthetic success, the relationship between esthetic outcomes and peri-implant bone parameters remains incompletely understood. In particular, limited evidence exists regarding the correlation between soft-tissue esthetic scores and radiographically assessed peri-implant bone changes following immediate implant placement with contemporary, biologically driven techniques such as VST, with or without adjunctive i-PRF.

Study Design:

This was a prospective interventional study.

Study Setting and Population:

Sample size:

Based on previously treated trial cases (Pink esthetic score after 6 months), we conducted a power analysis using "G*Power" ("version 3.1; Franz Faul, Universität Kiel, Germany"). A "priori: Compute required sample size analysis was performed to compute the necessary sample size", "given α, power, and effect size". "The input parameters were an α error probability of 0.05, an effect size (f) of 2.67, a power of 0.95", and 2 groups. The findings indicated a minimum sample size of n = 10 cases (5 per group). This was increased by 20% to compensate for any dropout—total sample size = 12 cases (6 per group).

Twelve (four males and eight females; age range: 20 to 39 years) patients participated in this study. They were seeking restoration of a hopeless anterior tooth; those attending the "outpatient clinic, Department of Oral Medicine, Periodontology, Oral Diagnosis and Oral Radiology, Faculty of Dental Medicine (Boys, Cairo), Al-Azhar University".

Eligibility criteria of the population

A-Inclusion Criteria: Patient has one hopeless tooth in the maxillary anterior region with TYPE II according to Elian classification of sockets [12] and sufficient bone apically and palatally. and age range from 18 to 50 years.

B-Exclusion Criteria: Grade III Extraction sockets [12], acute infection related to a hopeless tooth. [13] ,medically compromised patients according to the modified Cornell Medical Index [14]and Heavy smokers [15].

Ethical Consideration:

The nature of the study was explained to the patients; upon their agreement, they signed a written consent form. {Ethical number (921/1704)}

Initial therapy and patient grouping:

As part of the first clinical evaluation, we took the patient's medical and dental histories, checked their oral and overall health, and measured the area where the implant would eventually be placed. In order to determine the best course of implant therapy, CBCT scans were taken before to surgery utilizing the Planmeca ProMax 3D Mid to measure the patient's bone density, width, mesiodistal space, and inter-arch connection.

Every patient was given specific advice on how to properly care for their mouths before surgery. Quadrants underwent full-mouth scaling (both supra- and subgingival), root planing (also under local anesthetic). Ultrasonic scalers ("Cavitron Corp., Long Island City, NY" and hand Gracey curettes ("Hu Friedy, Chicago, IL") were used in this technique.

Patient grouping

Patients were randomly allocated to two groups using a coin toss.

A single coin flip was performed for each patient immediately after confirming eligibility: a head assigned the patient to Group 1, and a tail assigned the patient to Group 2. This randomization process ensured equal probability of assignment to either treatment group [16].

Group 1: Sockets with a deficient facial plate of bone and intact soft tissue will receive VST only.

Group 2: Sockets with a deficient facial plate of bone and intact soft tissue will receive VST and iPRF.

Surgical intervention

An aseptic procedure ensures a clean working environment and disinfects the perioral skin with solutions comprising povidone-iodine and alcohol.

The oral mucosa is disinfected with 0.2% chlorhexidine, which greatly lowers the bacterial count in saliva (17). Scaling and root planing were done when necessary as part of nonsurgical periodontal care after local anesthetic ("Articaine HCl 4% with Epinephrine 1:100,000, Inibsa Dental, Barcelona, Spain") was administered. Affective teeth were excised painlessly using periotomes ("Hu-Friedy Periotome, Chicago, IL, USA") after sulcular incisions were created under topical anesthetic. There was a curettage and socket lavage. The chosen implant system ("Anyridge, Megagen, Gyeongsan, South Korea") was used in conjunction with a progressive drill sequence to prepare the implant site. The implant shoulder was positioned 3 to 4 mm apical to the labial gingival boundary, and a tapered implant with "knife-edge threads" was inserted. At the socket location, 3–4 mm above the mucogingival junction, and 5–10 mm horizontally, a vestibular access incision was created. Beginning at the front of the socket opening and working its way up to the vestibular access incision, a submucoperiosteal tunnel was fashioned. Over the intact or deficient facial bone plate, a resorbable xenograft cortical membrane shield ("Flexible cortical bone sheet, Bioteck") was inserted via the tunnel and secured with bone tacks. It was cut to suit the socket's face wall.

In group one, xenograft (Bone A-Oss– by Osstem, Seoul, South Korea) was mixed with saline at a 1:1 ratio (0.5 g bone graft to 0.5 mL saline) and filled into the facial gap.

Group two, iPRF was prepared [18] immediately before the surgical procedure, 10–20 mL of venous blood was drawn from each patient using a sterile technique with 10 mL disposable syringes. Blood was collected into plain plastic tubes without anticoagulants to allow natural coagulation. All samples were processed immediately after collection to prevent premature clot formation. The collected blood was centrifuged using a tabletop centrifuge (Model TDZ5-WS, Changsha Xiangzhi Centrifuge Instrument Co., Ltd., Changsha, China) following the low-speed centrifugation concept (LSCC). Centrifugation was performed at 700 rpm for 3 minutes, which allows optimal separation while preserving platelets, leukocytes, and growth factors in the upper plasma layer.

After centrifugation, the upper, orange-colored liquid fraction, representing injectable platelet-rich fibrin (i-PRF), was carefully aspirated with a sterile syringe, mixed with xenograft bone, and packed into the facial gap.

Lastly, in order to achieve the desired soft-tissue emerging profile, the socket orifice was sealed using a tailored healing abutment that was fastened to the implant. The abutment had been sufficiently completed and polished. The horizontal incision for vestibular access was also sutured using 5/0 polypropylene threads. A broad-spectrum antibiotic ("Ciprodiazole, ciprofloxacin 500 mg/Metronidazole 500 mg [Minapharm Pharmaceutical"]) was provided to the patients twice daily beginning one day before the operation and continuing for five days after the procedure. For the first five days after surgery, patients were given a nonsteroidal anti-inflammatory medication ("Cataflam 50 mg [Novartis]") every eight hours. Avoiding mechanical damage to the surgical field and starting teeth brushing the day after surgery were among the patient's instructions, along with using cold packs for the first 6 hours after surgery and rinsing with 0.12% chlorhexidine mouthwash twice daily for 10 days. The sutures were taken out ten days after the procedure. The final restoration was sent out three months after the operation.

Observations:

Dental implants were evaluated esthetically and radiographically.

• *Esthetical parameter:*

Aesthetic appearance was assessed using the Pink Esthetic Score (PES) at 6 and 9 months. Before the study, two independent examiners underwent a calibration session to ensure standardization of PES evaluation.

The calibration process involved: (1) reviewing the original PES criteria and scoring methodology, (2) examining and scoring five clinical cases together to establish consensus, (3) independently scoring 10 additional cases, and (4) calculating inter-examiner reliability using Cohen's kappa coefficient ($\kappa > 0.80$ was considered acceptable agreement) [19]. During the study, both examiners were blinded to the treatment groups.

Photography Protocol

Patient Positioning Patient seated in upright position **,**Head positioned to align maxillary occlusal plane parallel to the floor**,** Relaxed facial expression with lips and cheeks retracted using appropriate retractors

Camera Positioning :Distance: Fixed distance of 30 cm from camera lens to subject (measured from anterior tooth surface) **Angle:** Camera positioned perpendicular to the long axis of the anterior teeth **Height:** Camera aligned with the mid-facial level of the anterior maxillary teeth

Standardization Requirements

Consistent lighting: flash system used to ensure uniform, reproducible lighting conditions

Magnification ratio: Maintained a consistent magnification ratio (typically 1:2 to 1:4) across all

photographs **Background:** Neutral background (black or blue retractor) to minimize distractions **Retraction:** Proper soft tissue retraction is done to visualize the gingival margins, papillae, and tooth structure **Focus:** Sharp focus on the region of interest (implant crown and surrounding soft tissue)
Image Capture Views : Full smile with lips retracted, showing maxillary anterior teeth

The PES assessment included "seven variables: mesial papilla, distal papilla, soft-tissue level, soft-tissue contour, alveolar process deficiency, soft-tissue color, and soft-tissue texture". "Each variable was scored on a 0-1-2 scale (0 = poorest, 1 = moderate, 2 = best esthetic outcome) by comparing the peri-implant soft tissue with the contralateral natural tooth, resulting in a maximum total score of 14". The final PES score for each patient was calculated as the mean of both examiners' scores [20].

Radiological assessment:

Cervical facial bone thickness and distance from the implant platform were radiographically evaluated using cone beam computed tomography (CBCT) at baseline, 6 months, and 9 months. Measurements were performed on standardized cross-sectional CBCT images, oriented perpendicular to the implant's long axis. Cervical facial bone thickness was defined as the linear distance from the outer surface of the implant to the external cortical surface of the facial bone at the crestal level [21]— measurement obtained by linear lines drawn on the cross-section.

RESULTS

Group 1 :

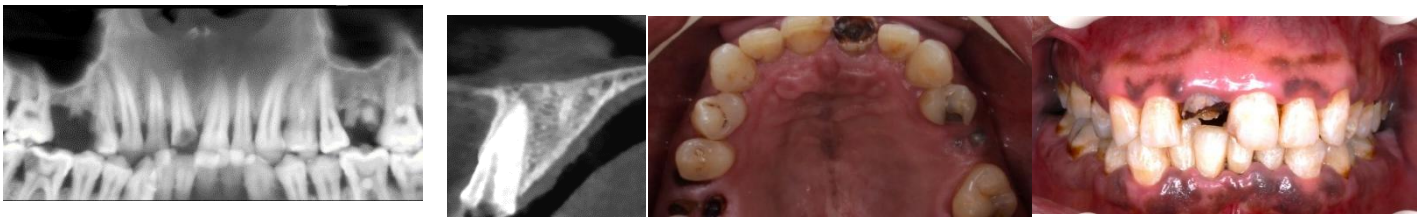

Fig. (1): preoperative radiograph and photographs

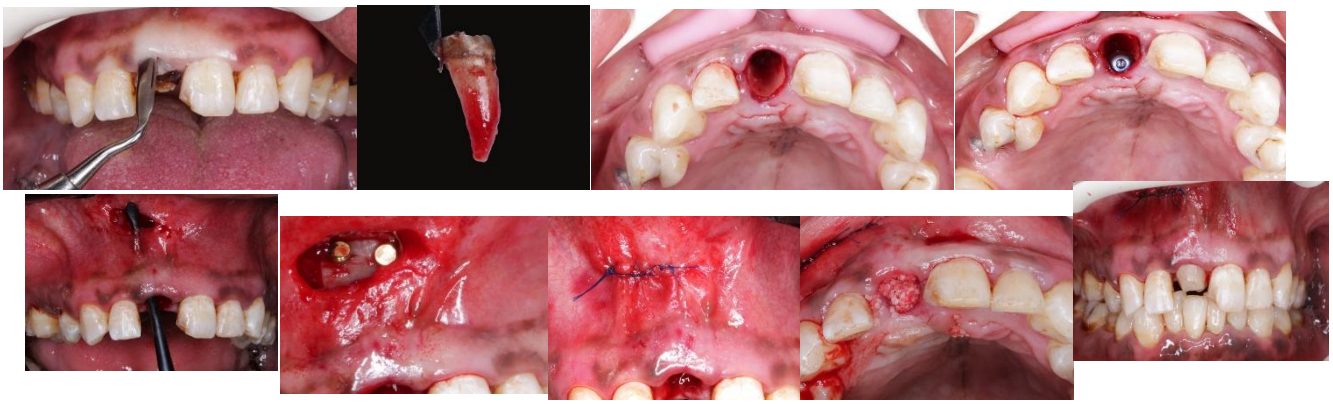

Fig. (2):VST surgical protocol

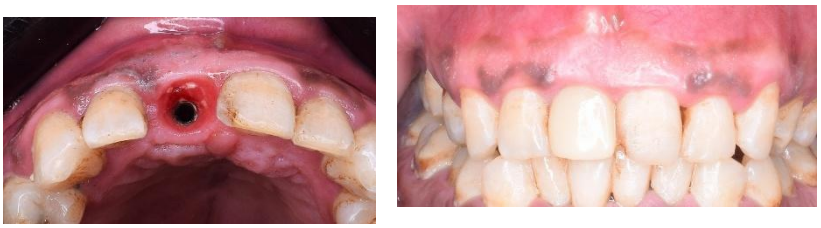

Fig. (3): final restoration after 3 month

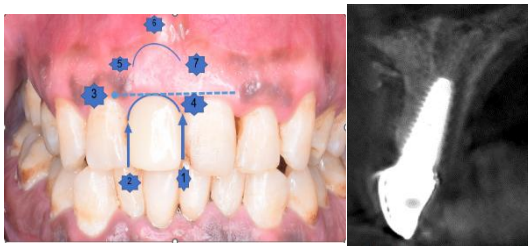

Fig. (4): 6 month isq, PES and cross section

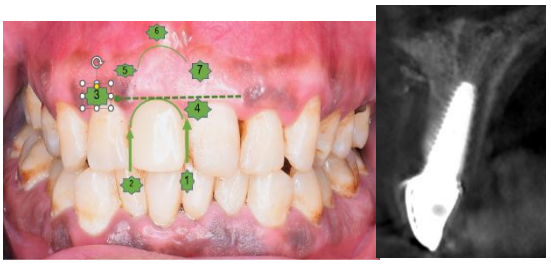

Fig. (5): 9 month isq, PES and cross section

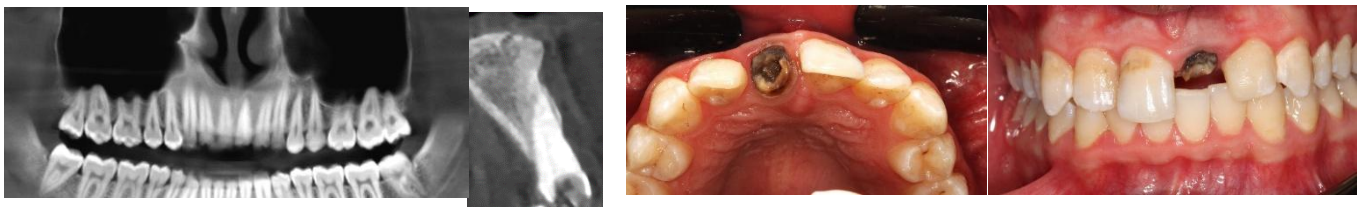

Fig. (6): preoperative radiograph and photographs

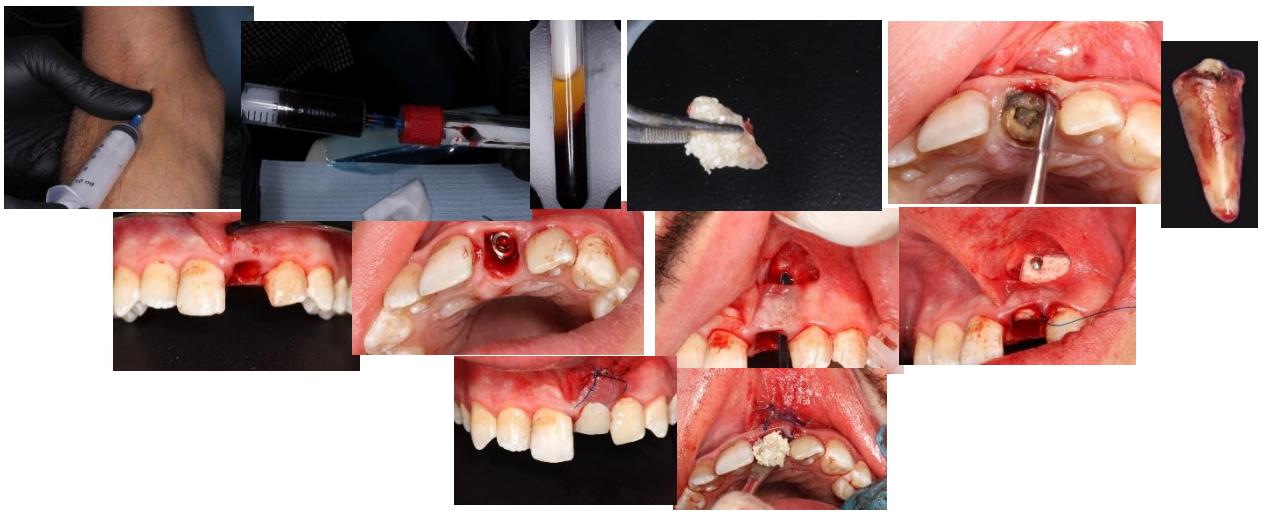

Fig. (7):VST surgical protocol with iPRF

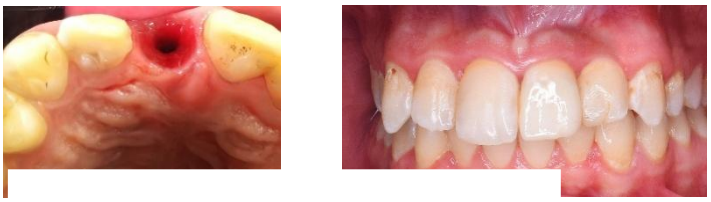

Fig. (8): final restoration after 3 month

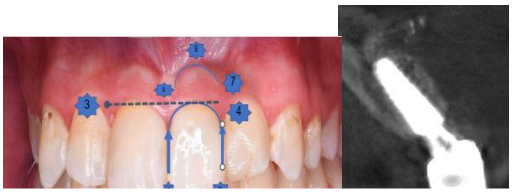

Fig. (9): 6 month isq, PES and cross section

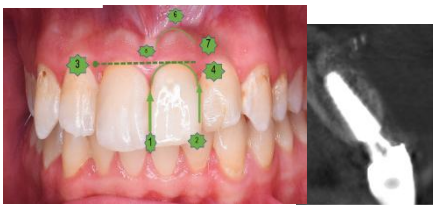

Fig. (10): 9month isq, PES and cross section

Descriptive statistics of base line characteristics are presented in Table ( ).

Table A1 : Descriptive statistics for base line characteristics in the two groups

Base line characteristics	Group I	Group II
Gender [n, (%)]		
Male	**3 (50%)**	**1 (16.7%)**
Female	**3 (50%)**	**5 (83.3%)**
Age [Mean, SD]	**27.5 (6.3)**	**31.8 (7)**

II. Pink Esthetic Score (PES)

Table 2: comparison between PES scores in the two groups

Time	Group I		Group II		*P*-value	*Effect size (d)*
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
6 months	11 (10, 12)	11.2 (0.8)	11.5 (11, 12)	11.5 (0.5)	0.423	0.425
9 months	12 (11, 13)	12.2 (0.8)	12.5 (12, 13)	12.5 (0.5)	0.423	0.425
P-value	0.014*		0.034*			
Effect size (d)	1		0.866			

**: "Significant at P ≤ 0.05"*

Cervical thickness (mm)

Table 3: comparison between cervical distance (mm) in the two groups

Time	Group I		Group II		*P*-value	*Effect size (Partial Eta squared)*
	Mean	SD	Mean	SD		
Base line	0 ^{C}	0	0 ^{C}	0	Not computed	
6 months	1.6 ^{B}	0.02	1.62 ^{B}	0.01	0.111	0.234
9 months	1.8 ^{A}	0.01	1.82 ^{A}	0.02	0.145	0.2
P-value	<0.001*		<0.001*			
Effect size (Partial Eta squared)	1		1			

**: "Significant at P ≤ 0.05, Different superscripts in the same column indicate statistically significant change by time within grou"p*

Distance from implant platform to crest of bone (mm)

Fig. (B3): A photograph showing occlusal view of the future implant site.

Fig. (B8): A photograph showing mixed bone graft with iPRF (Sticky bone)

Table 4: comparison between cervical distance (mm) in the two groups

Time	Group I		Group II		*P*-value	*Effect size (Partial Eta squared)*
	Mean	SD	Mean	SD		
Base line	-4 ^{C}	0	-4 ^{C}	0	Not computed	
6 months	0.5 ^{B}	0.02	0.52 ^{B}	0.01	0.111	0.234
9 months	1 ^{A}	0.02	1.02 ^{A}	0.02	0.062	0.306
P-value	<0.001*		<0.001*			
Effect size (Partial Eta squared)	1		1			

**: "Significant at P ≤ 0.05, Different superscripts in the same column indicate statistically significant change by time within group"*

Figure 3: mean and standard deviation values for distance in the two groups

the correlation analysis revealed a difference in PES between the two groups. Group 1 demonstrated excellent and statistically significant stability of PES over time (PES-6 vs PES-9), whereas Group 2 showed no significant association. In contrast, the relationships between PES and soft tissue thickness or distance at both 6 and 9 months were weak to moderate and statistically non-significant in both groups.

table (5): correlation analysis between the two groups according to PES and crestal bone thickness or distance at both 6 and 9 months

		Group 1 (r, p)	Group 2 (r, p)
PES			
PES 6 vs Thickness 6	r p	0.666, 0.149	0.516, 0.294
PES 6 vs Distance 6	r p	0.564, 0.244	0.516, 0.294
PES 9 vs Thickness 9	r p	0.666, 0.149	0.392, 0.442
PES 9 vs Distance 9	r p	0.564, 0.244	0.258, 0.621

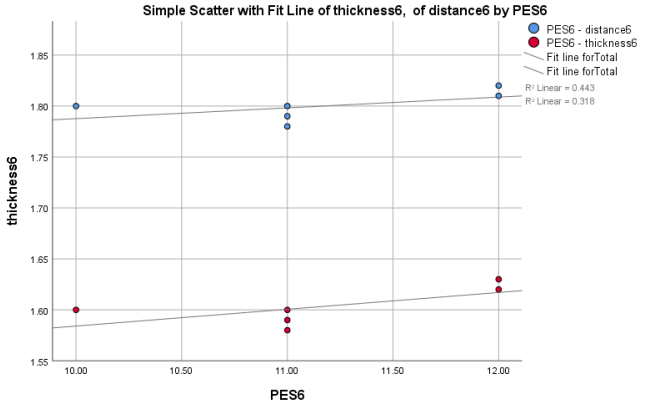

Figure 4: PES and crestal bone thickness or distance at 6 months of group I

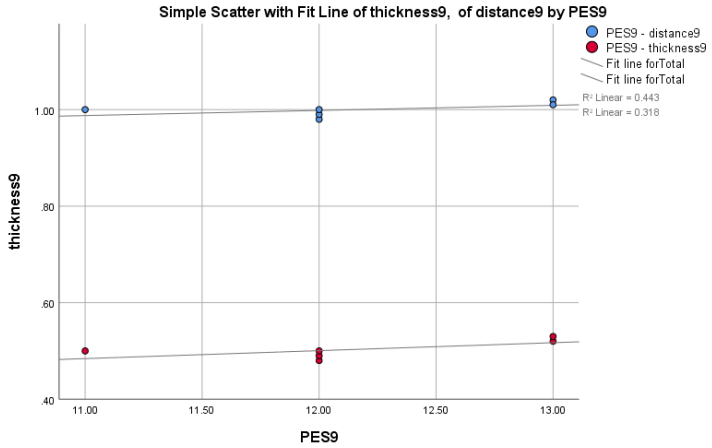

Figure 5: PES and crestal bone thickness or distance at 9 months of group I

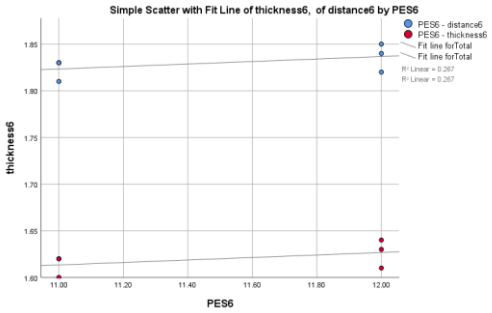

Figure 6: PES and crestal bone thickness or distance at 6 months of group II

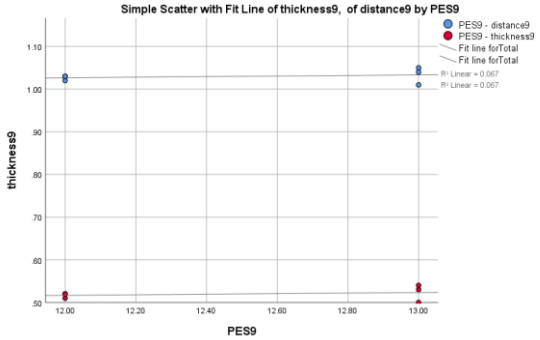

Figure 7: PES and crestal bone thickness or distance at 9 months of group II

DISCUSSION

The primary aim of the present study was to investigate the relationship between peri-implant soft-tissue esthetics, assessed by the Pink Esthetic Score (PES), and peri-implant bone parameters following immediate implant placement in defective fresh extraction sockets managed using vestibular socket therapy (VST), with or without adjunctive injectable platelet-rich fibrin (i-PRF). Specifically, the study sought to determine whether variations in cervical facial bone thickness and crestal bone level were associated with esthetic outcomes over time and whether the adjunctive use of i-PRF could influence this relationship.

A prospective interventional design was adopted, allowing standardized surgical and prosthetic protocols and longitudinal assessment of both esthetic and radiographic outcomes. The use of VST provided a biologically driven approach aimed at preserving the facial bone wall while minimizing disruption of the marginal soft tissues, a critical factor for esthetic stability in the anterior maxilla (6,7).PES was selected as the primary esthetic outcome measure due to its widespread validation and clinical relevance in evaluating peri-implant soft-tissue esthetics around single-tooth implants (20). Given the non-parametric distribution of PES values, appropriate statistical tests were applied, ensuring methodological rigor and reliability of the findings. Radiographic assessment using standardized CBCT imaging enabled precise evaluation of cervical facial bone thickness and crestal bone level changes over time.

Correlation analysis was performed to explore the potential association between soft-tissue esthetics and hard-tissue dimensional changes within each group and at different follow-up periods. This analytical approach was particularly relevant, as previous studies have primarily focused on independent assessment of soft- and hard-tissue outcomes, with limited emphasis on their interrelationship.

The results demonstrated that both treatment protocols resulted in favorable esthetic and radiographic outcomes over time. Intra-group analysis revealed statistically significant improvements in PES in both groups, indicating progressive soft-tissue maturation following immediate implant placement. However, inter-group comparison showed no statistically significant differences in PES at either 6 or 9 months, suggesting that the adjunctive use of i-PRF did not confer a measurable advantage in overall esthetic scores compared to VST alone.

Radiographically, both cervical facial bone thickness and crestal bone level showed significant intra-group increases over time, reflecting ongoing bone remodeling and stabilization following immediate implant placement. Nevertheless, inter-group comparisons revealed no statistically significant differences at any evaluation period, indicating comparable hard-tissue outcomes between the two treatment modalities.

Most importantly, correlation analysis revealed weak to moderate positive correlations between PES and peri-implant bone parameters in both groups at 6 and 9 months; however, none of these correlations reached statistical significance. These findings suggest that improvements in peri-implant soft-tissue esthetics occurred largely independently of measurable changes in cervical facial bone thickness or crestal bone level.

The absence of a statistically significant correlation between PES and peri-implant bone parameters aligns with previous clinical observations suggesting that multiple factors beyond bone dimensions alone influence soft-tissue esthetics. Chen and Buser (1) and Chappuis et al. (3) emphasized that although facial bone thickness plays a role in maintaining tissue stability, soft-tissue esthetics are also strongly affected by surgical technique, implant positioning, and prosthetic contouring. Kan et al. (4) reported that thin facial bone walls are associated with a higher risk of gingival recession; however, this does not necessarily translate into a direct linear relationship between bone thickness and esthetic scores, particularly when biologically driven techniques are employed. The present findings support this concept, as preservation of the facial bone framework using VST may have minimized the clinical impact of minor bone dimensional variations on soft-tissue esthetics. Recent studies have further highlighted that peri-implant soft-tissue quality and maturation may proceed independently of underlying bone remodeling. Cosyn et al. reported stable esthetic outcomes despite ongoing bone changes following immediate implant placement in the anterior maxilla (5). Similarly, Zucchelli et al. demonstrated that soft-tissue thickness and contour can be maintained through meticulous surgical and prosthetic management, even in sites with compromised facial bone (22).

Regarding biologic adjuncts, i-PRF has been shown to enhance angiogenesis and soft-tissue healing at the cellular level (8,18,21). However, emerging clinical evidence suggests that while i-PRF may support early healing and tissue quality, its influence on long-term hard-tissue dimensions and their relationship to esthetic outcomes remains limited (23,24). This may explain why the adjunctive use of i-PRF in the present study did not result in a stronger correlation between PES and bone parameters. Furthermore, recent systematic reviews have emphasized that esthetic success following immediate implant placement is multifactorial, with surgical timing, implant positioning, emergence profile design, and patient-related factors playing a dominant role (25–27). The present findings reinforce this concept by demonstrating that favorable esthetic outcomes can be achieved even in the absence of a strong association with quantitative bone measurements.

From a clinical perspective, the results suggest that predictable esthetic outcomes following immediate implant placement using VST may be achieved without relying solely on measurable increases in cervical facial bone thickness or crestal bone level. This highlights the importance of biologically respectful surgical techniques, soft-tissue preservation, and prosthetically driven planning in the esthetic zone. While i-PRF may offer biological benefits for wound healing and soft-tissue quality, its adjunctive use should be viewed as a supportive rather than a decisive factor in determining the relationship between peri-implant bone parameters and esthetic outcomes.

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