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Immediate implant placement in extraction sockets using i-PRF–enhanced bone grafts and amniotic membrane with zirconia crown rehabilitation: A clinical and digital radiographic evaluation

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Abstract:
Immediate implant placement remains challenged by marginal bone loss and peri-implant soft tissue instability despite its clinical advantages. Therefore, it is of interest to evaluate the effectiveness of i-PRF–enhanced bone grafts combined with amniotic membrane in 100 patients undergoing immediate implant placement and zirconia crown rehabilitation. Patients receiving i-PRF, bone graft and amniotic membrane showed significantly better plaque index, gingival index, probing depth, implant stability and marginal bone preservation than those receiving bone grafts alone ($p < 0.05$). The adjunctive use of i-PRF and amniotic membrane improved both clinical and radiographic outcomes during the 6-month follow-up period. Thus, combining i-PRF with amniotic membrane may enhance peri-implant tissue regeneration and implant stability, improving the predictability of immediate implant therapy.

Keywords: Immediate implant placement, Injectable platelet-rich fibrin (i-PRF), bone graft, amniotic membrane, zirconia crown

Background:
Immediate implant placement in fresh extraction sockets has emerged as a widely accepted treatment modality in modern implant dentistry, offering both functional and esthetic advantages. Traditionally, implant placement was delayed following tooth extraction to allow for complete healing of the alveolar bone **[1]**. However, this conventional approach is often associated with significant alveolar ridge resorption, particularly in the first three to six months after extraction. Such dimensional changes can compromise both the quantity and quality of bone available for future implant placement, leading to the need for additional augmentation procedures. Immediate implant placement, performed at the time of extraction, aims to minimize these post-extraction changes, reduce overall treatment time and enhance patient satisfaction **[2]**. Despite its advantages, immediate implant placement presents certain clinical challenges. One of the primary concerns is the presence of a gap between the implant surface and the walls of the extraction socket, commonly referred to as the jumping distance. If left unaddressed, this gap may lead to incomplete bone fill and compromise implant stability and long-term success. Furthermore, maintaining soft tissue architecture and achieving optimal esthetic outcomes, particularly in the anterior region, remain critical considerations **[3]**. To overcome these challenges, various regenerative approaches have been introduced, including the use of bone grafts, platelet concentrates and barrier membranes. In recent years, autologous platelet concentrates have gained significant attention in regenerative dentistry due to their ability to enhance wound healing and tissue regeneration. Injectable platelet-rich fibrin (i-PRF), a second-generation platelet concentrate, is particularly promising because of its ease of preparation and high concentration of growth factors such as platelet-derived growth factor (PDGF), transforming growth factor-beta (TGF-β) and vascular endothelial growth factor (VEGF) **[4]**. These growth factors play a crucial role in angiogenesis, cell proliferation and differentiation, thereby accelerating both soft and hard tissue healing. When combined with bone graft materials, i-PRF forms a cohesive sticky bone that improves handling characteristics, enhances graft stability and promotes osteogenesis within the defect site **[5]**. Bone

grafting in immediate implant placement serves to fill the peri-implant gap and support the surrounding alveolar bone **[6].** Various graft materials, including autografts, allografts, xenografts and alloplasts, have been used with varying degrees of success. Among these, xenografts and alloplasts are commonly preferred due to their availability and osteoconductive properties. The incorporation of i-PRF into these grafts further enhances their biological activity, potentially leading to improved bone regeneration and implant integration. This synergistic approach not only addresses the structural deficiencies but also enhances the biological environment for healing **[7]**. Another important component in guided bone regeneration is the use of barrier membranes. These membranes act as a physical barrier, preventing the ingrowth of epithelial and connective tissue cells into the bone defect, thereby allowing osteogenic cells to populate the area. Recently, amniotic membrane, derived from the innermost layer of the placenta, has gained popularity in dental applications due to its unique biological properties **[8]**. It is rich in collagen, growth factors and anti-inflammatory cytokines, which contribute to its regenerative potential. Additionally, amniotic membrane exhibits antimicrobial properties and reduces post-operative inflammation, thereby promoting faster healing and improved patient comfort. Its resorbable nature eliminates the need for a second surgical procedure for removal, making it a convenient option in clinical practice **[9]**. The prosthetic phase is equally critical in determining the long-term success of implant therapy **[10]**. Zirconia crowns have gained widespread acceptance as a restorative material due to their superior esthetic properties, high strength and excellent biocompatibility. Unlike metal-ceramic restorations, zirconia crowns provide enhanced translucency and color matching, making them particularly suitable for anterior restorations. Furthermore, zirconia exhibits low plaque affinity and favorable soft tissue response, which are essential for maintaining peri-implant health. The integration of zirconia crowns in immediate implant protocols contributes to achieving optimal functional and esthetic outcomes **[11]**. Advancements in digital radiographic techniques have further improved the assessment and monitoring of implant therapy. Digital radiography offers high-resolution images with reduced radiation exposure, allowing for precise evaluation of bone levels, implant positioning and peri-implant changes over time **[12]**. It also facilitates standardized measurements and reproducibility, which are essential for clinical research and outcome analysis. The use of digital radiographic evaluation in conjunction with clinical parameters provides a comprehensive understanding of treatment success and long-term stability **[13]**. Although individual components such as i-PRF, bone grafts, amniotic membranes and zirconia restorations have been extensively studied, there is limited literature evaluating their combined effect in immediate implant placement. The synergistic use of these advanced biomaterials and techniques has the potential to significantly enhance both hard and soft tissue outcomes, reduce complications and improve overall treatment predictability **[14].** Therefore, it is of interest to report the clinical and radiographic outcomes associated with the use of i-PRF–enhanced bone grafts and amniotic membrane in immediate implant placement with zirconia crown rehabilitation.

Methodology:

This study was designed as a prospective, randomized clinical trial conducted in the Department of Periodontology and Implantology of a tertiary dental care institution, with prior approval from the Institutional Ethical Committee and adherence to the Declaration of Helsinki and written informed consent obtained from all participants. A total of 100 patients requiring single-tooth extraction followed by implant rehabilitation were recruited from the outpatient department, with the sample size determined based on previous studies to ensure adequate statistical power. Patients aged 20–60 years with non-restorable teeth in the anterior or premolar regions, adequate bone volume, good general health and satisfactory oral hygiene were included, while individuals with uncontrolled systemic diseases, heavy smoking habits, pregnancy, active periodontal disease, local infection, history of radiotherapy, or medications affecting bone metabolism were excluded. The selected patients were randomly allocated into two groups of 50 each using a computer-generated method, where Group A received immediate implant placement with i-PRF–enhanced bone graft and amniotic membrane coverage followed by zirconia crown rehabilitation and Group B received implant placement with bone graft alone followed by zirconia restoration. Pre-operative evaluation included detailed clinical examination and radiographic assessment using digital intraoral periapical radiographs and/or CBCT, along with oral prophylaxis and hygiene instructions. For the test group, injectable platelet-rich fibrin was prepared by centrifuging 10 ml of venous blood at 700 rpm for 3 minutes to obtain the liquid fraction, which was mixed with particulate bone graft to form a cohesive sticky bone. All surgical procedures were performed under local anesthesia using strict aseptic protocols, with atraumatic extraction carried out to preserve socket integrity, followed by debridement and saline irrigation. Osteotomy preparation and implant placement were performed according to manufacturer guidelines, achieving primary stability of at least 30–35 Ncm and the peri-implant gap was managed according to group allocation, with Group A receiving i-PRF–enhanced graft and amniotic membrane coverage, while Group B received graft material alone, followed by primary closure using non-resorbable sutures. Post-operative care included antibiotics, analgesics and chlorhexidine mouth rinse, with suture removal after 7–10 days and regular follow-up for healing assessment. After a healing period of 3–4 months, implant stability was evaluated clinically and radiographically, followed by prosthetic rehabilitation using zirconia crowns fabricated under standardized protocols. Clinical parameters, including plaque index, gingival index, probing depth and implant stability, were recorded at baseline, 3 months and 6 months, while radiographic evaluation of marginal bone levels was performed using standardized digital intraoral periapical radiographs with the paralleling technique, measuring the

distance from the implant shoulder to the first bone-to-implant contact on mesial and distal aspects. The primary outcome measures included implant stability and marginal bone level changes, whereas secondary outcomes encompassed soft tissue healing, absence of complications and overall implant success rate. All data were analyzed using SPSS software, with descriptive statistics expressed as mean and standard deviation, intragroup comparisons performed using paired t-tests and intergroup comparisons analyzed using independent t-tests, with statistical significance set at $p < 0.05$. Ethical considerations were strictly maintained throughout the study, ensuring patient confidentiality, voluntary participation and the right to withdraw at any stage without compromising treatment.

Results:

A total of 100 patients were included in the study and completed the follow-up period of 6 months. No implant failures were reported in either group during the study duration, resulting in a 100% survival rate in both groups. Healing was uneventful in the majority of cases, with minimal post-operative complications. The mean age of patients in Group A was 38.6 ± 9.4 years, while in Group B it was 39.2 ± 8.8 years. There was no statistically significant difference in age or gender distribution between the two groups ($p > 0.05$), indicating comparability at baseline (**Table 1**). Both groups showed a reduction in Plaque Index (PI), Gingival Index (GI) and Probing Depth (PD) over time. However, Group A showed significantly better improvements compared to Group B at 3 and 6 months ($p < 0.05$) (**Table 2**). Implant stability values increased progressively in both groups. However, Group A showed significantly higher stability scores at both 3 and 6 months compared to Group B ($p < 0.05$) (**Table 3**). Marginal bone loss was observed in both groups over the study period. However, Group A exhibited significantly lesser bone loss compared to Group B at both 3 and 6 months ($p < 0.05$) (**Table 4**). STATA-based regression analysis further confirmed the significant influence of the treatment protocol on all evaluated outcomes. Group A showed significantly lower plaque index, gingival index, probing depth and marginal bone loss, along with significantly higher implant stability compared with Group B ($p < 0.05$). The regression coefficients and corresponding confidence intervals consistently favored the i-PRF–enhanced bone graft and amniotic membrane protocol **(Table 5)**. Soft tissue healing was superior in Group A, with better gingival contour and minimal inflammation. No cases of membrane exposure or graft loss were observed in the test group. In contrast, Group B showed slightly higher incidence of mild inflammation and delayed healing in some cases. The results of the present study showed that immediate implant placement with i-PRF–enhanced bone graft and amniotic membrane (Group A) yielded significantly better clinical and radiographic outcomes compared to conventional grafting alone (Group B). Group A showed superior soft tissue healing, reduced probing depth, improved implant stability and significantly less marginal bone loss over a 6-month follow-up period. These findings suggest that the combined use of i-PRF and amniotic membrane provides a favorable biological environment for enhanced implant success.

Table 1: Demographic characteristics of study population

Variable	Group A (n=50)	Group B (n=50)	p-value
Mean Age (years)	38.6 ± 9.4	39.2 ± 8.8	0.742
Male (n, %)	28 (56%)	30 (60%)	0.683
Female (n, %)	22 (44%)	20 (40%)	

Table 2: Comparison of clinical parameters between groups

Parameter	Time Interval	Group A (Mean ± SD)	Group B (Mean ± SD)	p-value
PI	Baseline	1.52 ± 0.32	1.49 ± 0.35	0.681
	3 months	0.82 ± 0.21	1.04 ± 0.27	0.003*
	6 months	0.61 ± 0.18	0.89 ± 0.22	0.001*
GI	Baseline	1.48 ± 0.29	1.46 ± 0.31	0.774
	3 months	0.76 ± 0.20	0.98 ± 0.25	0.002*
	6 months	0.58 ± 0.16	0.83 ± 0.21	0.001*
PD (mm)	Baseline	4.12 ± 0.56	4.08 ± 0.61	0.721
	3 months	3.12 ± 0.44	3.46 ± 0.52	0.004*
	6 months	2.76 ± 0.38	3.18 ± 0.47	0.001*

**Statistically significant*

Table 3: Comparison of implant stability (ISQ Values)

Time Interval	Group A (Mean ± SD)	Group B (Mean ± SD)	p-value
Baseline	64.5 ± 3.8	63.9 ± 4.1	0.412
3 months	72.8 ± 4.2	69.6 ± 3.9	0.001*
6 months	78.3 ± 3.6	74.2 ± 4.0	0.000*

Table 4: Comparison of marginal bone loss (mm)

Time Interval	Group A (Mean ± SD)	Group B (Mean ± SD)	p-value
3 months	0.48 ± 0.12	0.72 ± 0.18	0.001*
6 months	0.74 ± 0.16	1.12 ± 0.22	0.000*

Table 5: STATA-based statistical analysis summary

Variable	Coefficient (β)	Std. Error	t-value	p-value	95% Confidence Interval
Group (A vs B) – PI	-0.28	0.07	-4.00	0.001*	-0.42 to -0.14
Group (A vs B) – GI	-0.25	0.06	-4.16	0.001*	-0.37 to -0.13
Group (A vs B) – PD	-0.42	0.09	-4.66	0.000*	-0.60 to -0.24
Group (A vs B) – ISQ	+4.10	1.02	4.01	0.001*	2.08 to 6.12
Group (A vs B) – Bone Loss	-0.38	0.08	-4.75	0.000*	-0.54 to -0.22

**Statistically significant*

Discussion:

The present study evaluated the effectiveness of immediate implant placement using i-PRF–enhanced bone grafts and amniotic membrane, followed by zirconia crown rehabilitation. The findings showed significantly improved clinical parameters, enhanced implant stability and reduced marginal bone loss in the test group compared to the control group. These outcomes suggest that the combined use of i-PRF and biologic membranes creates a favorable regenerative environment, enhancing both soft and hard tissue healing. The results of the present study are in accordance with Iram *et al.* (2024), **[12]** who conducted a comparative clinical study on immediate implants with and without PRF. Their findings showed improved peri-implant bone density and healing in the PRF group, although marginal bone level differences were not statistically significant at early intervals. In contrast, the present study showed not only improved healing but also significantly reduced marginal bone loss at both 3 and 6 months. This difference may be attributed to the additional use of i-PRF in combination with bone graft and amniotic membrane, which enhances both osteogenesis and soft tissue regeneration. Similarly, Awasthi *et al.* (2025) **[13]** evaluated clinical outcomes of immediate implant placement with PRF and reported reduced implant mobility, improved bleeding on probing and better marginal bone levels in the PRF group. These findings strongly support the present study, where Group A exhibited significantly lower probing depth and better gingival health. However, the current study extends these observations by incorporating i-PRF with grafting material and membrane coverage, leading to more pronounced and consistent improvements. The beneficial effects of PRF on implant stability have also been showed by Öncü and Erbeyoğlu (2017), **[14]** who reported significantly higher implant stability and reduced marginal bone resorption in PRF-treated sites compared to controls. This is in direct agreement with the present study, where implant stability (ISQ values) was significantly higher in the test group at both follow-up intervals. The improved stability can be attributed to the sustained release of growth factors such as PDGF and TGF-β from i-PRF, which enhances early osseointegration. A case-based clinical report by Sehgal *et al.* (2018) **[15]** showed successful immediate implant placement with L-PRF in the esthetic zone, showing favorable esthetic outcomes and stable peri-implant tissues over a 12-month follow-up period. The present study corroborates these findings, particularly in terms of soft tissue healing and esthetic outcomes achieved with zirconia crown rehabilitation. Furthermore, Zhou *et al.* (2018) **[16]** reported enhanced bone regeneration around immediately placed implants using autologous PRF, emphasizing its role in accelerating healing and improving bone quality. This aligns with the radiographic findings of the present study, where significantly less marginal bone loss was observed in the I-PRF group. The concept of sticky bone formed by mixing i-PRF with graft material likely contributed to improved graft stability and osteoconduction. Despite variations in methodology and follow-up durations among the studies, a consistent trend emerges supporting the positive role of platelet concentrates in immediate implant dentistry. However, the present study provides more comprehensive evidence by integrating multiple regenerative modalities and evaluating both clinical and radiographic parameters over time.

Conclusion:

I-PRF–enhanced bone graft and amniotic membrane showed significantly superior clinical and radiographic outcomes compared to conventional grafting alone. This combined approach resulted in improved implant stability, enhanced soft tissue healing and reduced marginal bone loss over the 6-month follow-up period. Therefore, the integration of i-PRF and amniotic membrane can be considered a predictable and effective strategy for optimizing success in immediate implant therapy.

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