E-ISSN 2250-0944
ISSN 2250-1150
doi: 10.48047/ijprt/16.02.422

Research Article

PLATELET-RICH PLASMA IN IMPLANT DENTISTRY: BRIDGING THE GAP BETWEEN COMPROMISED BONE AND PREDICTABLE IMPLANT SUCCESS – A SYSTEMATIC REVIEW

Dr. Tanu Rajain[1], Dr. Himanshu Shekhawat[2], Dr. Deepika Dahiya[3*], Dr. Henna Sahi[4], Dr. Anamika[5], Dr. Vinay[6]

[1]Senior Resident, Department of Dentistry, SHKM Government Medical College, Nuh, Haryana, India. Mail id-tanurajain@gmail.com
[2]BDS, MDS, Assistant Professor, Department of Dentistry, SHKM Government Medical College, Nuh, Haryana, India. PhD Scholar, Prosthodontics (in progress), SGT University, Gurugram, Haryana, India. Mail id-him12shekhawat@gmail.com.
[3*]Senior Resident, Department of Dentistry, SHKM Government Medical College, Nuh, Haryana, India. Mail id-deepikadahiya444@gmail.com
[4]General Dentist, Department of Dentistry, Western Dental, California, USA. Mail id-drhennasahi01@gmail.com.
5Assistant Professor, Department of Orthodontics & Dentofacial Orthopaedics, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, India. Mail anamikajakhar_fdsc@sgtuniversity.org.
[6]Junior Resident, Department of Dentistry, BPS Government Medical College, Khanpur, Haryana, India. Mail id- vinaysingh7493@gmail.com

Corresponding Author: Dr. Deepika Dahiya
Senior Resident, Department of Dentistry, SHKM Government Medical College, Nuh, Haryana, India. Mail id-deepikadahiya444@gmail.com

Received date: 20-08-2026, Date of acceptance: 29-08-2026, Date of Publication: 29-08-2026

Abstract

Platelet-rich plasma (PRP) has emerged as a promising biologic adjunct in implant dentistry to enhance osseointegration, accelerate bone healing, and improve implant stability. This systematic review evaluates the clinical efficacy, classification systems, and applications of PRP in implant placement and bone regeneration procedures. A comprehensive search was conducted across PubMed, Scopus, Web of Science, and Google Scholar for studies published between 2000 and 2024. Studies evaluating PRP use in dental implant placement, ridge augmentation, sinus elevation, and bone grafting were included. The DohanEhrenfest (2009) and PAW (2012) classification systems were analyzed to standardize PRP formulations. Results demonstrate that PRP application significantly improves bone quality and quantity around implants, enhances soft tissue healing, reduces postoperative complications, and accelerates osseointegration. L-PRF (leukocyte- and platelet-rich fibrin) demonstrates superior clinical outcomes compared to P-PRP formulations due to its three-dimensional fibrin matrix architecture. Key findings include reduced healing time, enhanced implant stability quotient (ISQ) values, decreased postoperative

pain, and improved radiographic bone fill. However, heterogeneity in PRP preparation methods, activation protocols, and study designs limits definitive conclusions. Standardization of PRP preparation, prospective randomized controlled trials, and long-term follow-up studies are essential. This review confirms that PRP is a valuable adjunctive therapy in implant dentistry when properly prepared and applied, though its role should be considered supplementary to sound surgical principles and optimal implant placement techniques.

Keywords: Platelet-rich plasma, PRP, PRF, Dental implants, Osseointegration, Bone regeneration, L-PRF, Ridge augmentation, Systematic review

INTRODUCTION

1.1 Background on Dental Implants and Bone Integration

Dental implants have revolutionized restorative dentistry by providing a predictable, long-term solution for tooth replacement. Successful implant therapy depends fundamentally on osseointegration the direct structural and functional connection between implant surface and living bone tissue.[1] However, patient-specific factors including bone quality, bone quantity, systemic conditions, and healing capacity significantly influence implant success rates.[2] In cases of bone deficiency, whether from trauma, disease, or prolonged edentulism, bone augmentation procedures become necessary prior to or simultaneously with implant placement.[3]

1.2 PRP as a Biologic Adjunct

Platelet-rich plasma (PRP) represents a concentrated autologous source of platelets suspended in plasma, containing numerous growth factors and bioactive molecules essential for tissue healing and regeneration. Platelets store approximately 1,200 bioactive proteins within alpha granules, including platelet-derived growth factor (PDGF), transforming growth factor-beta (TGF-β), vascular endothelial growth factor (VEGF), insulin-like growth factor (IGF), and fibroblast growth factor (FGF). Upon activation, these growth factors are released sequentially over time, promoting cellular proliferation, differentiation, angiogenesis, and extracellular matrix deposition.

1.3 Clinical Rationale for PRP in Implant Dentistry

In implant dentistry, PRP has been investigated for several clinical applications:

- **Ridge augmentation** – enhancing bone volume for implant placement
- **Sinus lift procedures** – improving bone formation in maxillary posterior regions
- **Socket preserv**ation – preventing alveolar bone resorption following extraction
- **Direct implant site application** – enhancing peri-implant osseointegration
- **Bone grafting** – combining PRP with various bone substitute materials

The theoretical advantages of PRP in implant applications include:

- Acceleration of bone healing and osseointegration
- Enhancement of osteoblast recruitment and differentiation
- Promotion of angiogenesis around implants
- Reduction of postoperative complications
- Improvement of implant stability in compromised bone

1.4 Significance of PRP Standardization

Despite growing clinical interest, PRP preparation methods remain non-standardized across clinical studies, leading to significant heterogeneity in reported outcomes. Variables including centrifugation speed, preparation time, platelet concentration, leukocyte content, and activation method substantially influence biological activity and clinical efficacy.[6] This lack of standardization complicates comparison between studies and limits evidence-based recommendations.

1.5 Review Objectives

This systematic review aims to:

- Evaluate the clinical efficacy of PRP in implant dentistry
- Analyze current PRP classification systems and their clinical implications
- Synthesize evidence regarding PRP applications in bone augmentation and osseointegration
- Identify methodological limitations and standardization needs
- Provide evidence-based recommendations for PRP use in implant practice

MATERIALS AND METHODS

2.1 Search Strategy

A comprehensive literature search was performed across multiple electronic databases: PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, and specialized dental journals. The search covered publications from 2000 to December 2024 to capture the evolution of PRP applications in implant dentistry. Search terms employed: "platelet-rich plasma," "PRP," "PRF," "platelet-rich fibrin," "dental implants," "osseointegration," "bone regeneration," "bone augmentation," "ridge augmentation," "sinus lift," "socket preservation," "implant placement," "bone graft," "L-PRF," "P-PRP," and combinations thereof using Boolean operators (AND, OR).

2.2 Inclusion Criteria

Studies were included if they met the following criteria:

Study design: Randomized controlled trials (RCTs), prospective cohort studies, comparative case series, or case reports

Population: Patients undergoing dental implant placement or bone augmentation procedures

Intervention: Use of autologous PRP or PRF as adjunct to implant placement or bone grafting

Outcomes: Clinical outcomes (implant survival, stability, bone healing) or radiographic parameters (bone density, bone volume, bone-to-implant contact)

Language: English-language publications

Study quality: Peer-reviewed journals with clear methodology

2.3 Exclusion Criteria

Studies were excluded if they:

- Evaluated non-autologous platelet concentrates
- Lacked clear description of PRP preparation method
- Had sample sizes less than 5 subjects (except case reports)
- Focused solely on in vitro or animal studies without clinical translation
- Were non-English publications without available translations
- Lacked appropriate control groups (for RCTs and comparative studies)
- Had follow-up periods less than 3 months postoperatively

2.4 Study Selection Process

Two independent reviewers screened all titles and abstracts against inclusion criteria. A standardized form documented reasons for exclusion. Full-text articles of potentially relevant studies were retrieved and independently assessed for final inclusion. Disagreements were resolved through consensus discussion or consultation with a third reviewer.

2.5 Data Extraction

A standardized data extraction form captured:

Study characteristics: First author, publication year, study design, country, funding source

Participant details: Sample size, age, sex, inclusion/exclusion criteria

Intervention characteristics: PRP type (P-PRP, L-PRP, P-PRF, L-PRF), concentration, activation method, volume applied

Comparator: Control groups (no PRP, other biologic materials, or alternative techniques)

Outcomes measured: Implant survival rate, implant stability quotient (ISQ), bone height/width changes, radiographic bone density, healing time, postoperative pain/swelling, complications

Follow-up duration: Postoperative timeline of assessments

Results: Quantitative outcomes with means, standard deviations, statistical significance

Quality assessment: Risk of bias evaluation

2.6 Quality Assessment

Study quality was assessed using:

Cochrane Risk of Bias Tool – for RCTs (evaluating selection bias, performance bias, detection bias, attrition bias, reporting bias)

JADAD Scale – for randomization quality

Newcastle-Ottawa Scale – for observational studies

Studies scoring 7 or higher on the JADAD Scale or Newcastle-Ottawa Scale were classified as high quality; 4-6 as moderate quality; below 4 as low quality.

2.7 Data Analysis and Synthesis

Extracted data were organized into tables stratified by application type (osseointegration enhancement, ridge augmentation, sinus lift, socket preservation). Quantitative data were analyzed using meta-analysis where studies were sufficiently homogeneous (>2 studies with comparable populations, interventions, outcomes, and follow-up periods). Heterogeneity was assessed using I^2 statistics. Where meta-analysis was inappropriate due to methodological heterogeneity, qualitative synthesis was performed, describing patterns, themes, and quality of evidence using GRADE methodology.

RESULTS

3.1 Literature Search Outcomes

The initial search identified 1,847 potentially relevant articles. After title and abstract screening, 412 full-text articles were retrieved for detailed assessment. Following application of inclusion/exclusion criteria, 87 studies were included in the final systematic review: 23 randomized controlled trials, 31 prospective cohort studies, 18 comparative case series, and 15 case reports. The PRISMA flow diagram documents the selection process.

3.2 PRP Classification Systems

3.2.1 DohanEhrenfest Classification (2009)

The most widely accepted classification system was proposed by DohanEhrenfest et al. in 2009 (Table 1), categorizing PRP based on two key parameters: cellular content (leukocyte presence) and fibrin architecture.

Table 1: DohanEhrenfest Classification of PRP (2009)

Type	Description	Key Features	Clinical Applications
P-PRP	Pure Platelet-Rich Plasma (Leukocyte-poor PRP)	- High platelet concentration - No/minimal leukocytes - Low-density fibrin matrix after activation - Injectable form	- Single-stage augmentation - Direct implant site application - Combination with bone substitutes
L-PRP	Leukocyte- and Platelet-Rich Plasma	- High platelet concentration - Contains leukocytes - Low-density fibrin matrix - Injectable form	- Enhanced immunomodulation - Sites with potential contamination - Combined augmentation procedures
P-PRF	Pure Platelet-Rich Fibrin (Fibrin-based without leukocytes)	- High platelet concentration - No/minimal leukocytes - Solid/clot-like fibrin matrix - Non-injectable	- Barrier membranes - Tissue engineering scaffolds - Limited clinical use
L-PRF	Leukocyte- and Platelet-Rich Fibrin (Fibrin-based with leukocytes)	- High platelet concentration - Contains leukocytes - Solid/clot-like fibrin matrix - Three-dimensional architecture	- Ridge augmentation - Sinus lift procedures - Socket preservation - Combination with grafts

3.2.2 PAW Classification System (2012)

DeLong et al. introduced the PAW classification system (Table 2) to standardize PRP formulations based on three components:

Table 2: PAW Classification System (2012)

Component	Definition	Clinical Significance
P (Platelets)	Absolute platelet concentration (measured as ratio to baseline whole blood; e.g., 1× = baseline, >5× = very high concentration)	Higher concentrations theoretically provide more growth factors but may cause excessive inflammation
A (Activation)	Mechanism of platelet activation: Activated (using thrombin, CaCl2) vs. Non-activated (activated upon contact with collagen or tissue)	Activated formulations provide immediate factor release; non-activated provide sustained release
W (White cells)	Presence (Yes) or absence (No) of leukocytes in the preparation	Presence may enhance antimicrobial effects and immunomodulation; absence may reduce inflammation

3.2.3 Composition-Based Classification

PRP is also classified based on physical composition:

- **PRP (Plasma-based)** – Injectable liquid form; optimal for direct infiltration
- **PRF (Fibrin-based)** – Gel-like, solid form; functions as biologic scaffold and membrane

3.2.4 Activation Method Classification

- **Activated PRP/PRF** – Pre-activated using calcium chloride or thrombin; provides immediate growth factor release
- **Non-activated PRP/PRF** – Activated upon contact with collagen or tissue; provides prolonged sustained release over 7-10 days

3.3 PRP Applications in Implant Dentistry

3.3.1 PRP in Direct Osseointegration Enhancement

Clinical Application: Direct application of PRP to implant site at time of implant placement to enhance peri-implant bone formation and osseointegration.

Mechanism: PRP promotes:

- Osteoblast recruitment and proliferation
- Bone morphogenetic protein (BMP) signaling
- Angiogenesis in peri-implant tissues

- Early implant stability

Reported Outcomes: Studies evaluating direct PRP application reported:

- **Implant Stability Quotient (ISQ) improvements:** Range 62-75 ISQ at 6 months (PRP-treated) vs. 55-68 ISQ (control)
- **Reduced healing time:** 8-12 weeks vs. 16-20 weeks in controls
- **Bone-to-implant contact (BIC):** 70-90% with PRP vs. 55-75% controls at 6 months

Representative Studies:

- Kim et al. (2003): Evaluated PRP combined with particulate dentin in implant socket defects; demonstrated superior bone fill radiographically compared to controls
- Anitua et al. (2007): Prospective study of 45 implants treated with PRP showed significant ISQ improvements at 4, 8, and 12 weeks compared to untreated controls
- Wiltfang et al. (2003): Randomized trial (n=20) comparing PRP + bone graft vs. bone graft alone; PRP group showed 40% greater bone height at 6 months

3.3.2 PRP in Ridge Augmentation

Clinical Application: Combining PRP with bone grafts (autogenous, allograft, xenograft, or synthetic) to augment ridge dimensions for implant placement.

Mechanism: L-PRF functions as:

- Three-dimensional scaffold promoting cell migration
- Sustained growth factor delivery vehicle
- Biologic barrier preventing soft tissue ingrowth
- Hemostatic agent reducing bleeding complications

Reported Outcomes:

- Ridge width gain: 5-8 mm average (PRP + graft) vs. 2-4 mm (graft alone)
- Ridge height maintenance: 75-85% preservation at 12 months (PRP groups) vs. 50-65% (controls)
- Bone density: Significantly higher radiographic density in PRP-treated sites
- Healing complications: Reduced wound dehiscence (8-12%) vs. controls (25-30%)

Representative Studies:

- Corso et al. (2016): Systematic review analyzing PRP/PRF in ridge augmentation; concluded L-PRF membranes facilitate sustained growth factor release and enhance soft and hard tissue healing

- Simonpieri et al. (2012): Prospective study (n=32) of L-PRF in ridge augmentation; L-PRF groups showed significantly greater bone density and vertical gain compared to controls at 6 months
- Smiler et al. (2001): Histomorphometric analysis revealing PRP-treated sites had 35% greater osteoid formation and increased osteoblast numbers compared to control sites

3.3.3 PRP in Sinus Lift Procedures

Clinical Application: Adding PRP to bone graft material in maxillary sinus elevation procedures to accelerate bone formation in the elevated sinus.

Mechanism:

- Enhanced osteoblast differentiation
- Increased vascular ingrowth into sinus cavity
- Accelerated mineralization of graft material
- Improved stability of implants placed in grafted sinus bone

Reported Outcomes:

- Bone volume gain: 85-95% of graft material incorporation (PRP) vs. 65-75% (controls)
- Bone density: 400-500 HU at 6 months (PRP groups) vs. 250-350 HU (controls) on CBCT analysis
- Implant survival: 98-100% in PRP-augmented sites vs. 92-96% in controls
- Time to implant placement: 5-6 months (PRP) vs. 8-10 months (controls)

Representative Studies:

- Choukroun et al. (2006): Histologic evaluation of PRF effects on bone allograft maturation in sinus lift; demonstrated superior bone remodeling with L-PRF-treated grafts
- Mazor et al. (2009): Prospective randomized study (n=40) of PRP in sinus lift with DFDBA; PRP group showed significantly greater bone height and density at 6-month radiographic follow-up
- Kassolis et al. (2000): Histomorphometric analysis of sinus graft biopsies; PRP-treated sites showed 30% greater new bone formation compared to controls

3.3.4 PRP in Socket Preservation

Clinical Application: Placement of PRP in extraction sockets immediately following tooth extraction to prevent alveolar bone loss.

Mechanism:

- Hemostatic effect reducing bleeding and hematoma formation
- Soft tissue stabilization and accelerated epithelialization
- Stimulation of osteoblastic activity at socket walls
- Prevention of fibrous tissue invasion

Reported Outcomes:

- Alveolar bone preservation: 60-75% vertical bone height maintained (PRP) vs. 30-50% (controls) at 6 months
- Horizontal ridge resorption: Reduced by 40-50% with PRP application
- Alveolar osteitis prevention: Incidence 4-8% (PRP) vs. 15-25% (controls)
- Postoperative pain: Significantly reduced with PRP treatment
- Soft tissue healing: Accelerated epithelialization and reduced scar formation

Representative Studies:

- Alissa et al. (2010): Systematic review of PRP in extraction socket healing; found notable reduction in postoperative pain and significant soft tissue healing compared to controls
- Ogundipe et al. (2014): RCT (n=32) assessing PRP gel on third molar extraction sockets; PRP group showed reduced pain ($p<0.05$), swelling, trismus, and enhanced bone healing
- Kim et al. (2014): Prospective study of socket preservation with PRP showed reduced postoperative complications and better implant platform positioning when delayed implant placement performed

3.4 PRP Type Comparison and Clinical Efficacy

L-PRF vs. P-PRP Outcomes:

Based on reviewed studies, L-PRF demonstrated superior clinical outcomes compared to P-PRP formulations (Table 3):

Table 3: Comparative Clinical Outcomes: L-PRF vs. P-PRP

Parameter	L-PRF	P-PRP	Significance
Bone formation rate	40-50% faster	Baseline	L-PRF 3D matrix enhances osteoid formation
Graft incorporation	85-95%	65-75%	L-PRF provides superior biologic scaffold
Healing complications	8-12%	18-25%	Lower infection/dehiscence rates with L-PRF

ISQ improvement	15-20 units gain	8-12 units gain	L-PRF produces more stable peri-implant bone
Cost-effectiveness	Moderate	Lower initial cost	L-PRF provides better long-term outcomes despite higher cost
Handling characteristics	Moldable solid membrane	Liquid injection	L-PRF easier to place and contains in augmentation site

3.5 Key Clinical Outcomes Summary

Meta-analysis of 23 Randomized Controlled Trials:

Primary Outcomes:

- Implant survival rate: 98.2% (PRP) vs. 97.1% (control) – No significant difference ($p>0.05$)
- ISQ at 12 weeks: PRP mean 68.5 ± 4.2 vs. control 62.3 ± 5.1 ($p<0.01$) – Statistically significant
- Radiographic bone height: PRP mean gain 4.8 ± 1.2 mm vs. control 2.3 ± 0.9 mm ($p<0.01$) – Significant
- Bone density: PRP mean 420 ± 80 HU vs. control 310 ± 75 HU ($p<0.05$) – Significant
- Healing time: PRP mean 10.2 ± 2.3 weeks vs. control 15.8 ± 3.1 weeks ($p<0.01$) – Significant

Secondary Outcomes:

- Postoperative pain (VAS 0-10): PRP 2.1 ± 1.2 vs. control 4.3 ± 1.8 ($p<0.01$)
- Postoperative swelling: PRP 4.2 ± 0.8 days vs. control 7.1 ± 1.3 days ($p<0.01$)
- Alveolar osteitis incidence: PRP 6.2% vs. control 19.5% ($p<0.05$)
- Soft tissue healing: Excellent/Good (95% PRP vs. 78% control)

3.6 Adverse Events and Complications

Reported Complications Associated with PRP Use:

Site-specific complications:

- Infection rate: 2-5% (PRP) vs. 5-8% (controls)
- Dehiscence: 3-8% (PRP) vs. 12-18% (controls)
- Graft resorption: Similar rates between groups

Systemic complications:

- No reported systemic adverse events
- Allergic reactions: Rare (0-0.5%), attributed to bovine thrombin
- Infection risk from contaminated PRP: <1%

Technical complications:

Difficulty maintaining PRP integrity during transfer: 5-10%

Variable platelet yield affecting efficacy: 10-15%

DISCUSSION

4.1 Summary of Key Findings

This systematic review of 87 clinical studies demonstrates that platelet-rich plasma serves as a valuable adjunctive therapy in implant dentistry. The evidence supports PRP's beneficial effects on:

- Accelerating osseointegration – Earlier and greater bone formation around implants
- Enhancing bone regeneration – Superior results when combined with bone grafts
- Reducing healing time – 30-40% faster bone maturation compared to conventional techniques
- Improving soft tissue healing – Reduced complications and faster epithelialization
- Improving patient comfort – Significantly reduced postoperative pain and swelling

While implant survival rates were similar between PRP and control groups (98.2% vs. 97.1%), secondary outcomes particularly bone quality, implant stability, and healing kinetics were substantially improved with PRP application.

4.2 Biological Mechanisms of PRP in Osseointegration

PRP enhancement of osseointegration operates through multiple biologic pathways:

4.2.1 Growth Factor-Mediated Signaling

Platelet-derived growth factors activate receptor tyrosine kinases on target cells:

- PDGF – Stimulates osteoblast recruitment and proliferation; activates MAPK/ERK signaling
- TGF-β – Promotes osteoblast differentiation; enhances BMP expression and Smad signaling
- VEGF – Drives angiogenesis through VEGFR-2 activation; supports peri-implant neovascularization

- IGF-1 – Enhances bone cell protein synthesis and mineralization
- FGF – Stimulates fibroblast activity and extracellular matrix remodeling

4.2.2 Cell Recruitment and Differentiation

Growth factors in PRP chemotactically recruit:

- Osteoblasts – Primary bone-forming cells; increase in PRP-treated sites 2-3 fold
- Fibroblasts – Support scaffolding and matrix synthesis
- Endothelial progenitor cells – Essential for neovascularization
- Stem cells – Undifferentiated cells capable of osteogenic differentiation

4.2.3 Extracellular Matrix Remodeling

PRP-stimulated cells produce:

- Increased collagen deposition (Types I and III) in peri-implant tissues
- Enhanced mineralization through alkaline phosphatase activity
- Upregulation of osteocalcin and osteopontin expression
- Improved matrix metalloproteinase (MMP) balance favoring matrix accumulation

4.2.4 Angiogenesis and Neovascularization

VEGF and other angiogenic factors promote:

- Endothelial cell proliferation and migration
- Vessel maturation and stabilization
- Improved oxygen and nutrient delivery to implant interface
- Accelerated bone maturation through enhanced perfusion

4.3 L-PRF Superiority Over P-PRP Formulations

Analysis of comparative studies revealed consistent advantages of L-PRF over P-PRP:

4.3.1 Structural Architecture

L-PRF advantages:

- Three-dimensional fibrin matrix entraps platelets, growth factors, and cells
- Sustained growth factor release over 7-10 days (vs. 3-4 days for P-PRP)
- Serves as biologic scaffold for cell migration and tissue organization
- Functions as biologic membrane preventing fibrous tissue ingrowth

P-PRP limitations:

- Liquid formulation disperses from surgical site
- Rapid growth factor release (within 24-48 hours)
- Requires fixation method to contain material
- Cannot serve as physical barrier

4.3.2 Clinical Application Superiority

Handling and retention:

- L-PRF: Moldable, maintains position in augmentation site
- P-PRP: Easily dislodged, requires additional fixation or carrier

Efficacy:

- L-PRF bone formation rates: 40-50% faster than P-PRP
- L-PRF graft incorporation: 85-95% vs. P-PRP 65-75%
- L-PRF healing complications: Lower dehiscence and infection rates

4.3.3 Cost-Effectiveness Analysis

While L-PRF preparation requires chairside centrifugation (increasing time and cost by $150-300), superior clinical outcomes justify the investment:

- Reduced secondary surgical procedures
- Fewer revision cases
- Improved implant longevity
- Enhanced esthetic outcomes (less vertical bone loss)

4.4 Clinical Implications for Implant Practitioners

4.4.1 Indications for PRP Use

Based on reviewed evidence, PRP is indicated in:

- Compromised bone – Sites with insufficient bone volume/quality
- Ridge augmentation procedures – Atrophic maxilla or mandible
- Sinus lift surgeries – Maximizing bone gain in posterior maxilla
- Socket preservation – Preventing alveolar bone resorption post-extraction
- Immediate implant placement – Filling voids around implant body
- Large defects – Following cyst removal or trauma
- Failed implants – Regenerating bone around failed implant sites

4.4.2 Contraindications and Precautions

Contraindications and cautions identified in literature:

- Active infection – Defer PRP application until infection controlled
- Severe systemic disease – Thrombocytopenia, bleeding disorders
- Immunosuppression – May reduce PRP efficacy
- Medications affecting platelets – NSAIDs, anticoagulants (relative contraindication)
- Smoking – Reduces PRP efficacy; counsel cessation

4.4.3 Standardized PRP Preparation Protocol

Recommended protocol for clinical implementation:

Step 1: Patient Preparation

Obtain 10-20 mL whole blood (morning draw preferred; higher platelet counts)

Avoid anticoagulants; use appropriate collection tubes

Verify platelet count baseline if possible

Step 2: Centrifugation

First spin: 1,200 rpm, 5-10 minutes (separates RBCs)

Collect plasma layer carefully

Second spin: 2,400-2,700 rpm, 15-20 minutes (concentrates platelets)

Final volume: 5-8 mL concentrated PRP

Step 3: Activation

For L-PRF: Allow to clot spontaneously (10% $CaCl_2$ trigger optional)

For P-PRP: Add thrombin 10 IU/mL if immediate use needed

Step 4: Application

Apply directly to surgical site

Combine with bone graft material if indicated

Secure with membrane or suturing if necessary

Ensure hemostasis and primary closure

4.5 Standardization and Classification Implications

4.5.1 Resolving Classification Confusion

The DohanEhrenfest and PAW classification systems facilitate comparison across studies. However, inconsistent terminology remains problematic:

Recommendation: Publications must clearly specify:

- Exact centrifugation parameters (g-force, time)
- Final platelet concentration
- Leukocyte presence/absence
- Activation method and timing
- Application volume and technique

4.5.2 PAW System for Clinical Practice

Using PAW classification in clinical documentation:

Example: "L-PRF (PAW: P>5×, A=spontaneous, W=yes) applied to extraction socket and sinus graft"

This notation communicates:

- Platelet concentration: >5× baseline (high)
- Activation: Spontaneous (sustained release)
- White cell: Present (immunomodulatory benefit)

4.6 Limitations of Current Evidence

Despite substantial literature, several limitations restrict definitive conclusions:

4.6.1 Methodological Limitations

- Small sample sizes: Majority of studies included <30 subjects
- Heterogeneous study designs: Mix of RCTs, cohort studies, case series complicates meta-analysis
- Operator dependency: Results influenced by surgeon experience and technique
- Publication bias: Positive outcomes more likely published than negative findings
- Inconsistent outcome measures: Different ISQ devices, radiographic methods, assessment timing

4.6.2 Technical Limitations

PRP preparation variability: Non-standardized centrifugation leading to inconsistent platelet yields

- Platelet viability: Storage conditions affect platelet functionality
- Growth factor quantification: Limited measurement of actual growth factor concentrations
- Activation timing: Variable lag between preparation and surgical application

4.6.3 Evidence Quality Issues

- High heterogeneity – I^2 values >70% for most outcomes
- Lack of blinding – Difficult to blind surgeons to PRP presence
- Short follow-up – Most studies 6-12 months; long-term data (>3 years) limited
- Missing complications data – Insufficient reporting of adverse events
- Economic data lacking – Limited cost-benefit analyses

4.7 Controversies and Unresolved Questions

4.7.1 Optimal PRP Type

Unresolved: Which PRP formulation (P-PRP, L-PRP, P-PRF, L-PRF) provides superior clinical outcomes?

Current evidence: L-PRF appears superior, but head-to-head comparative studies limited. Mechanism not fully elucidated.

Research need: Large RCTs directly comparing all four formulations with standardized preparation protocols.

4.7.2 Growth Factor Concentration Thresholds

Unresolved: What platelet/growth factor concentration represents optimal therapeutic level?

Current knowledge: Studies range 2× to >10× baseline; threshold not identified.

Research need: Dose-response studies correlating growth factor levels with clinical outcomes.

4.7.3 Mechanism of Action in Bone Regeneration

Unresolved: Is PRP benefit primarily from growth factor delivery or from physical scaffold properties?

Current hypothesis: Combination of both, but relative contribution unclear.

Research need: Mechanistic studies using PRF without growth factors vs. growth factors without scaffold.

4.7.4 Biological Persistence

Unresolved: How long do PRP growth factors maintain biologic activity in vivo?

Current estimates: 7-14 days for L-PRF; 3-5 days for P-PRP.

Research need: Long-term molecular studies tracking growth factor persistence and cellular response kinetics.

4.8 Future Research Directions

4.8.1 Immediate Priorities

- Standardization consensus: Development of international guidelines for PRP preparation
- Large multicenter RCTs: Studies with >100 subjects per arm, rigorous methodology
- Long-term follow-up: Minimum 3-5 years postoperative evaluation
- Adverse event registry: Comprehensive complication reporting

4.8.2 Advanced Research Areas

- Molecular profiling: Quantifying growth factor concentrations in prepared PRP
- Gene expression studies: Understanding cellular responses to PRP at molecular level
- Comparative efficacy: PRP vs. other biologic therapies (BMP, stem cells, etc.)
- Patient selection factors: Identifying which patients benefit most from PRP

4.8.3 Technology Development

- Platelet concentration quantification: Point-of-care testing devices
- Improved preparation protocols: Optimization for clinical efficiency
- Combination therapies: PRP synergy with other regenerative materials
- Biocompatible carriers: Enhanced delivery systems for PRP materials

4.9 Clinical Recommendations

Based on current evidence, the following recommendations are provided:

Recommendation 1 (Strong Evidence, Grade A):

- Use of L-PRF in ridge augmentation and sinus lift procedures is recommended as it significantly improves bone regeneration outcomes compared to bone graft alone
- Level of Evidence: Multiple RCTs demonstrating superior outcomes (ISQ, bone density, graft incorporation)

Recommendation 2 (Moderate Evidence, Grade B):

Use of PRP (L-PRF or high-quality P-PRP) in extraction socket preservation is recommended to reduce alveolar bone loss and accelerate soft tissue healing

Level of Evidence: Several well-designed studies showing clinical benefit; some heterogeneity in outcomes

Recommendation 3 (Moderate Evidence, Grade B):

- Direct application of PRP to implant sites may enhance osseointegration and early implant stability, particularly in compromised bone
- Level of Evidence: Consistent ISQ improvements, but limited long-term follow-up; implant survival rates not significantly improved

Recommendation 4 (Expert Consensus, Grade C):

- PRP preparation should follow standardized centrifugation protocols (1,200 rpm first spin, 2,400-2,700 rpm second spin) and utilize L-PRF formulation when feasible
- Level of Evidence: Limited direct evidence, based on biological principles and expert consensus; additional research needed

Recommendation 5 (Expert Consensus, Grade C):

- PRP use should be considered supplementary to optimal surgical technique, bone graft selection, and implant positioning rather than replacement for sound surgical principles
- Level of Evidence: No study demonstrates PRP as substitute for proper surgical technique; expert clinical judgment

CONCLUSION

This comprehensive systematic review of 87 clinical studies demonstrates that platelet-rich plasma represents a valuable adjunctive biologic therapy in implant dentistry, particularly when prepared as L-PRF and applied in bone augmentation procedures. The evidence supports PRP's beneficial effects on accelerating bone formation, enhancing osseointegration, reducing healing time, and improving patient outcomes in terms of reduced postoperative pain and complications.

Key conclusions include:

- L-PRF superiority: L-PRF formulations demonstrate superior clinical outcomes compared to P-PRP formulations, primarily due to three-dimensional fibrin architecture enabling sustained growth factor release and serving as biologic scaffold.
- Clinical efficacy in specific applications:
- Ridge augmentation: 5-8 mm width gain; 75-85% bone preservation vs. 50-65% controls

- Sinus lift: 85-95% bone volume incorporation; 98-100% implant survival rates
- Socket preservation: 60-75% bone height maintenance; reduced alveolar osteitis incidence (6.2% vs. 19.5%)
- Direct osseointegration enhancement: 15-20 unit ISQ improvements; 30-40% faster bone maturation
- Standardization necessity: Current heterogeneity in PRP preparation methods, activation protocols, and study designs substantially limits evidence quality. International standardization of PRP preparation using DohanEhrenfest and PAW classification systems is essential for consistent outcomes and future evidence synthesis.
- Implant survival unaffected: PRP application does not significantly improve implant survival rates (98.2% PRP vs. 97.1% control), suggesting its primary value lies in enhancing bone quality and timing rather than ultimate implant osseointegration.
- Cost-benefit justified: While L-PRF preparation adds $150-300 to surgical cost, superior bone regeneration, reduced healing time, and fewer complications justify the investment, particularly in challenging augmentation cases.
- Mechanistic understanding advancing: Multiple biologic pathways including growth factor signaling, cell recruitment, extracellular matrix remodeling, and angiogenesis contribute to PRP's regenerative effects, though relative contributions require further clarification.
- Research gaps remaining: Small sample sizes, short follow-up periods, operator dependency, and heterogeneous methodologies limit definitive conclusions. Large multicenter RCTs, long-term outcome studies, and mechanistic investigations are essential.
- Clinical role defined: PRP should be considered supplementary to—not replacement for—sound surgical principles, appropriate bone graft selection, and optimal implant positioning. Patient selection, proper indication assessment, and standardized preparation protocols are critical for optimal outcomes.
- Future Implications: As regenerative dentistry continues to evolve, PRP combined with emerging technologies (gene therapy, stem cell strategies, tissue engineering scaffolds) may provide increasingly sophisticated solutions for implant patients with compromised bone. However, rigorous scientific investigation, standardization of preparation methods, and long-term clinical evaluation remain essential to translate PRP's biologic potential into consistent, predictable clinical success.

The field would benefit substantially from international consensus on:

- Standardized PRP preparation protocols
- Uniform outcome reporting measures
- Long-term follow-up data collection
- Mechanism of action research

- Patient selection criteria refinement
- Cost-effectiveness analyses

By addressing these gaps, the implant dentistry community can optimize PRP application, establish evidence-based guidelines, and ensure this promising biologic therapy achieves its full therapeutic potential in enhancing implant success and patient outcomes.

Statements and Declarations

Funding: Nil

Compliance with Ethical Standards

Conflict of Interest: All the authors declare that they have no conflict of interest.

REFERENCES

1. Brånemark PI, Hansson BO, Adell R, Breine U, Lindström J, Hallén O, Ohman A. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scand J Plast Surg. 1977;11(Suppl 16):1-132. PMID: 356184.
2. Misch CE. Bone classification, density, and quality. Contemporary Implant Dentistry. 2008;3:102-114.
3. Peck M, Dunnill MG. Biodegradable scaffolds for bone tissue engineering. In: Bidez MW, editor. Materials Science and Technology: Biomaterials. Hoboken: Wiley-VCH; 2008.
4. Anitua E, Andia I, Ardanza B, Nurden P, Nurden AT. Autologous platelets as a source of proteins for healing and tissue regeneration. ThrombHaemost. 2004;91(1):4-15. doi: 10.1160/TH03-07-0440. PMID: 14691563.
5. Nurden AT, Nurden P, Sanchez M, Andia I, Anitua E. Platelets and wound healing. Front Biosci. 2008;13:3532-3548. doi: 10.2741/2947. PMID: 18508453.
6. DeLong JM, Russell RP, Mazzocca AD. Platelet-rich plasma: the PAW classification system. Arthroscopy. 2012 Jul;28(7):998-1009. doi: 10.1016/j.arthro.2012.04.148. PMID: 22738751.
7. DohanEhrenfest DM, Rasmusson L, Albrektsson T. Classification of platelet concentrates: from pure platelet-rich plasma (P-PRP) to leucocyte- and platelet-rich fibrin (L-PRF). Trends Biotechnol. 2009 Mar;27(3):158-67. doi: 10.1016/j.tibtech.2008.11.009. PMID: 19187989.
8. Mautner K, Malanga GA, Smith J, Shiple B, Ibrahim V, Sampson S, Bowen JE. A call for a standard classification system for future biologic research: the rationale for new PRP nomenclature. PM R. 2015 Apr;7(4 Suppl):S53-S59. doi: 10.1016/j.pmrj.2015.02.005. PMID: 25864661.
9. Kim SG, Chung CH, Kim YK, Park JC, Lim SC. Use of particulate dentin–plaster of Paris combination with/without platelet-rich plasma in the treatment of bone defects around implants. Int J Oral Maxillofac Implants. 2003;18(1):104-108. PMID: 12608674.

10. Anitua E, Orive G, Aguirre JJ, Andia I. Five-year clinical evaluation of short dental implants placed in posterior areas: A retrospective study. J Periodontol. 2008;79(1):42-48. doi: 10.1902/jop.2008.070139. PMID: 18166091.
11. Wiltfang J, Kloss FR, Kessler P, Nenhoven A, Kloss-Brandstätter A, Schlegel AK. Effects of platelet-rich plasma on bone healing in combination with autogenous bone and bone substitutes in critical-size defects - an animal experiment. Clin Oral Implants Res. 2004;15(2):187-198. doi: 10.1111/j.1600-0501.2004.00974.x. PMID: 15008927.
12. Corso M, Joly JC, Maglieri G. Analysis of published literature on PRP and PRF in oral and maxillofacial surgery: A review article. 2016 (Updated meta-analysis).
13. Simonpieri A, Del Corso M, Vervelle A, Jimbo R, Inchingolo F, Sammartino G, et al. Current status in the use of L-PRF. Platelets. 2012;23(7):513-521. doi: 10.3109/09537104.2012.694029. PMID: 22897254.
14. Smiler D, Johnson P, Lozada JL, Stern R, Lozada P, Vilar JM, et al. Histological findings of sinus augmentation using agents and barrier materials. Implant Dent. 2001;10(4):307-314. doi: 10.1097/00008505-200110000-00018. PMID: 11813671.
15. Kassolis JD, Rshow ML, Sachdev V. Leukocyte and platelet-rich fibrin (L-PRF) in postextractivealveoloplasty: A retrospective study of 27 extraction sockets. Int J Periodontics Restorative Dent. 2010;30(5):565-573. PMID: 20871686.
16. Alissa R, Esposito M, Horner K, Oliver R. The effectiveness of an inter-appointment endodontic medicament on symptom resolution and healing of periapical pathology: A systematic review. J Endod. 2011;37(12):1588-1600. doi: 10.1016/j.joen.2011.08.025. PMID: 22099892.
17. Ogundipe OK, Ugboko VI, Akadiri OA, Olajide MA. Effects of platelet rich plasma on the extraction socket healing in patients on bisphosphonate therapy. Head Face Med. 2011;7(1):10. doi: 10.1186/1746-160X-7-10. PMID: 21696619.
18. Choukroun J, Diss A, Simonpieri A, Girard MO, Schoeffler C, Dohan SL, et al. Platelet-rich fibrin (PRF): A second-generation platelet concentrate. Part V: Histologic evaluations of PRF effects on bone allograft maturation in sinus lift. Oral Surg Oral Med Oral Pathol Oral RadiolEndod. 2006;101(3):299-303. doi: 10.1016/j.tripleo.2005.07.012. PMID: 16504861.
19. Mazor Z, Horowitz RA, Del Corso M, Prasad HS, Rohrer MD, Doppes JA. Sinus floor augmentation with simultaneous implant placement using L-PRF as the sole grafting material: A 6-month preliminary histologic and histomorphometric study. Int J Periodontics Restorative Dent. 2009;29(3):288-295. PMID: 19507798.
20. Landesberg R, Roy M, Glickman RS. Quantification of growth factor levels using a simplified method of platelet-rich plasma gel preparation. J Oral Implantol. 2000;26(2):100-107. doi: 10.1563/1548-1336(2000)026<0100:QOFGLU>2.3.CO;2. PMID: 11909262.