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T-PRF IN PERIODONTAL REGENERATION: BIOLOGY, STRUCTURE AND CLINICAL APPLICATION

Periodontology

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ABSTRACT

By offering an autologous source of growth factors and fibrin scaffolds, platelet concentrates have transformed regenerative therapy in periodontics. A modification of traditional platelet-rich fibrin (PRF), titanium-prepared platelet-rich fibrin (T-PRF) was created to get around the drawbacks of silica-based activation techniques. T-PRF increases fibrin polymerization, extended growth factor release, and platelet activation by using titanium tubes. The resulting fibrin matrix promotes angiogenesis, osteogenesis, and soft tissue repair due to its better mechanical and biological qualities. The biological foundation, preparation method, structural benefits, and clinical uses of T-PRF are all thoroughly examined in this review, along with its drawbacks and potential uses in periodontal therapy in the future.

KEYWORDS

Platelet Concentrates, Titanium PRF, Periodontal Regeneration, Growth Factors

1. INTRODUCTION

By using the patient's own biological mediators to promote tissue regeneration and wound healing, the idea of autologous platelet concentrates has greatly enhanced regenerative techniques in periodontology. Newer adjustments have been created to enhance handling characteristics and biological efficacy after platelet-rich plasma (PRP)[1] evolved into platelet-rich fibrin (PRF)[2]. One of these, titanium-prepared platelet-rich fibrin (TPRF), is a novel, second-generation platelet concentrate made to get beyond some of the drawbacks of traditional PRF production.

Tunali presented a variation of PRF that uses titanium tubes during centrifugation rather than conventional glass tubes.[3] This invention is justified by titanium's higher hemocompatibility and biocompatibility, which are known to promote fibrin polymerization and platelet activation. Titanium offers a more physiologic surface than glass, which can release silica particles. This could result in a denser and more ordered fibrin matrix that is enhanced with platelets, leukocytes, and growth factors.

TPRF has drawn interest in periodontology because it may improve the healing of both soft and hard tissues. The fibrin scaffold functions as a three-dimensional matrix that promotes angiogenesis, cell migration, and the long-term release of important growth factors like vascular endothelial growth factor (VEGF), transforming growth factor-beta (TGF-β), and platelet-derived growth factor (PDGF). These biological mediators are essential for neovascularization, periodontal regeneration, and inflammatory regulation.

Additionally, compared to traditional PRF, TPRF has better mechanical strength and handling qualities, which makes it appropriate for a range of periodontal applications, such as implant therapy, intrabony defect management, guided tissue regeneration, and root covering operations. It is thought that the improved structural integrity of the fibrin network may optimize healing outcomes by prolonging the release of bioactive molecules and improving stability at the surgical site.

2. Evolution of Platelet Concentrates: By providing autologous growth factors within a fibrin scaffold, platelet concentrates have evolved to improve wound healing and regeneration.

Table 2: Generations of Platelet Concentrates[4]

Generation	Type	Key Features	Limitations	Key Author
1st Generation	PRP (Platelet Rich Plasma)	• High platelet concentration • liquid form	• Requires anticoagulants & bovine thrombin • Rapid release of growth factors • Complex preparation	Marx (1998) 1
2nd Generation	PRF (Platelet Rich Fibrin)	• No anticoagulant • Natural polymerization • Formation of 3D fibrin scaffold, slow release	• Silica contamination • Weak fibrin network	Choukroun (2001) 2
3rd Generation	Advanced PRF variants (A-PRF, i-PRF, T-PRF)	• Improved biological activity, dense fibrin network • Thicker fibrin network • Better cellular entrapment • Slower resorption	Technique sensitive	Tunali (2012) 3

3. Concept of T-PRF

The basic idea underlying T-PRF is that platelet activation and fibrin production are influenced by the surface characteristics of the blood collection tube.

- Surface-Dependent Activation: Platelets react very strongly to surface properties. The following mechanisms cause platelet activation when blood comes into touch with a foreign surface:
  - ✓ αIIbβ3 Integrin receptors
  - ✓ Activation of glycoprotein IIb/IIIa
- Titanium causes:[5]
  - ✓ Increased adherence of platelets
  - ✓ A more powerful activation cascade
  - ✓ Enhanced production of thrombin

As a result, fibrin polymerization is more effective and improved cell entrapment

Table 2: Conceptual Difference Between PRF and T-PRF

Feature	PRF (Glass Tubes)	T-PRF (Titanium Tubes)
Activation	Silica-mediated	Titanium surface-mediated
Polymerization	Moderate	Enhanced
Fibrin network	Loosely organized	Dense, mature
Contamination	Possible (silica)	None
Growth factor release	Moderate	Sustained

4. Composition of T-PRF

T-PRF is composed of[3]:

Table 4: Cellular Components

Component	Function
Platelets	Growth factor release
Neutrophils	Early inflammation
Macrophage	Tissue remodeling
Lymphocytes	Immune regulation
Fibrin	Scaffold

Table 5: Growth Factors and Functions

Growth Factor	Function
PDGF	Fibroblast proliferation, chemotaxis
TGF-b	Collagen synthesis, osteoblast differentiation
VEGF	Angiogenesis
IGF	Cell proliferation
EGF	Epithelial healing

6. PREPARATION PROTOCOL OF T-PRF

6.1 Principle of Preparation

The utilization of titanium tubes serves as a biocompatible surface for platelet activation and impact fibrin polymerization and clot architecture.

6.2 Step-by-Step Preparation Protocol

Ten milliliters of whole blood are drawn into sterile titanium tubes devoid of anticoagulant right after venipuncture. To avoid early clotting, the blood must be centrifuged immediately (within 1-2 minutes). After that, the tubes are spun for 12 minutes at about 2700 rpm, however the centrifuge's calibration may cause some deviations.[3]

Following centrifugation, three distinct layers are formed:

- A lower layer of red blood cells
- A middle layer consisting of the T-PRF clot
- An upper layer of platelet-poor plasma (PPP)

Using sterile tools, the T-PRF clot is carefully extracted from the tube and separated from the RBC layer. A membrane that can be utilized in a number of regeneration techniques can then be created by gently compressing the clot using sterile gauze or a PRF box.

8. Mechanism of Action of T-PRF

The fibrin matrix serves as a dynamic scaffold, while entrapped platelets and leukocytes act as biological mediators that regulate the healing cascade.

8.1 Platelet Activation and Growth Factor Release

Platelets activate and degranulate when they come into contact with the titanium surface, releasing a range of growth factors that are stored in alpha granules. These growth factors are essential for the production of extracellular matrix, migration, differentiation, and cell proliferation. T-PRF offers a sustained release of growth factors over a longer period of time (up to 14 days), in contrast to PRP, which releases growth factors quickly.[8]

8.2 Fibrin Matrix as a Biological Scaffold

Strong cross-linking and delayed polymerization define the fibrin matrix of T-PRF, creating a three-dimensional structure.

This matrix makes it easier for:

- ✓ Migration of cells (fibroblasts, osteoblasts, endothelial cells)
- ✓ Integrins-mediated cell adhesion
- ✓ Release of growth factors gradually

Such a physiologic fibrin network, according to Dohan et al., encourages ordered tissue regeneration as opposed to quick but chaotic repair.[6]

8.3 Angiogenesis

Angiogenesis is essential to periodontal regeneration because it guarantees waste elimination, nutrient delivery, and oxygen supply. T-PRF stimulates angiogenesis is by releasing VEGF and PDGF, which increase the migration and proliferation of endothelial cells. Furthermore, the fibrin matrix promotes neovascularization by acting as a scaffold for capillary ingrowth. This leads to better tissue maturation and faster wound healing.

8.4 Osteogenesis and Bone Remodeling

By encouraging osteoblast development and mineralization, T-PRF significantly contributes to bone regeneration. Growth factors that trigger intracellular signaling pathways include TGF-β and PDGF.

- ✓ The MAPK pathway
- ✓ The Smad signaling pathway
- ✓ Activation of the transcription factor Runx2

The RANKL/OPG pathway, which is essential for bone remodeling, is also modulated by T-PRF. Research has demonstrated that T-PRF inhibits osteoclastogenesis and promotes bone formation by decreasing RANKL expression and raising osteoprotegerin (OPG) levels.[10]

8.5 Immunomodulatory Effects

Leukocytes found in T-PRF aid in the management of infection and immunity. T-PRF plays a crucial role in maintaining a balanced inflammatory response, which avoids excessive inflammation. This regulated inflammation is necessary for the best possible healing results.

9. Clinical Application

Table 6: Randomized Clinical Trials on T-PRF

Author (Year)	Study Design	Sample	Comparison	Key Findings	Reference
Tunali et al. (2012)	Experimental study	Animal/ human	PRF vs T-PRF	Denser fibrin, slower resorption	3
Arabaci et al. (2018)	Split-mouth RCT	Intrabony defects	OFD vs OFD + T-PRF	Significant PD reduction, CAL gain	7
Ozdemir et al. (2024)	RCT	Intrabony defects	PRF vs T-PRF	Better bone fill and healing	11
Thakur et al. (2025)	Clinical study	Endo-perio lesions	PRF vs T-PRF	T-PRF superior outcomes	12

Table 7: T-PRF in Gingival Recession (Systematic Review Evidence)

Study	Comparison	Outcome	Reference
Gajbhiye et al. (2025)	T-PRF vs CTG	Comparable root coverage	13

10. Limitations and Controversies

T-PRF is linked to some controversies despite its encouraging outcomes. Variability in results is caused by the absence of standardized preparatory procedures. Variations in handling methods, tube design, and centrifugation conditions can affect the end product's biological characteristics.

Furthermore, there are not enough long-term randomized controlled trials, which makes it challenging to prove clear-cut clinical superiority over PRF, even though short-term clinical findings are favorable. More research is needed to determine the precise extent to which titanium is superior to glass tubes.

11. Recent Advances

In order to maximize growth factor release and handling characteristics, recent advancements in platelet concentrates include advanced PRF (A-PRF), injectable PRF (I-PRF), and sticky bone approaches. T-PRF may improve regeneration results when combined with growth factor delivery methods, biomaterials, and stem cells.

12. CONCLUSION

With its better fibrin architecture, increased biocompatibility, and prolonged biological activity, T-PRF is a major breakthrough in

platelet concentrate technology. It is a useful adjunct in periodontal and implant therapy because of its capacity to stimulate angiogenesis, osteogenesis, and soft tissue healing. Further study is necessary to establish standardized techniques and long-term clinical advantages, despite the encouraging existing results. As a biologically based regenerative material, T-PRF has a lot of promise and fits perfectly with the ideas of contemporary minimally invasive dentistry.

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