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Review Article

Platelet Concentrates as Biofunctional Coatings for Dental Implants: A Mini-Review

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Abstract

The long-term success of dental implants depends not only on osseointegration but also on the establishment of a stable and healthy peri-implant soft tissue seal. Titanium is the most commonly used implant material, but biological and aesthetic limitations have led to the search for alternatives. Zirconia provides metal-free esthetics but with mechanical risks. Polyetheretherketone (PEEK) has emerged as a promising candidate due to its bone-like elastic modulus. However, the biological inertness of PEEK results in limited protein adsorption, cellular attachment, and tissue integration. Hence, surface modification strategies are required. Autologous platelet concentrates have attracted increasing attention as a biofunctional surface coating due to their sustained release of growth factors such as TGF-β, PDGF, and VEGF, which are known to induce gingival fibroblast proliferation, collagen synthesis, and soft tissue repair. This mini review aims to provide an overview of the current evidence regarding dental implant materials, implant surface modification strategies, and the potential role of platelet concentrates as a biofunctional coating for improving the biological performance of dental implants. The results indicate that platelet concentrates may represent a promising strategy to improve cellular responses and tissue healing around implant surfaces.

Keywords: Dental Implants; Platelet Concentrates; PRP; Gingival Fibroblasts

Introduction

Dental implants have become one of the most predictable and successful treatment options for patients with missing teeth. Since the introduction of the concept of osseointegration by Brånemark, the field of implant dentistry has developed remarkably, with a continuous evolution of the materials and the strategies to optimize the performance of the implant surface. The long-term success of an implant relies on osseointegration, the biological process by which the implant surface achieves direct structural and functional connection with living bone [1,2].

This process is influenced by implant design, surface characteristics, patient-related factors and surgical technique. Consequently, considerable research has been directed to changing implant materials and surfaces to improve tissue integration and reduce healing time. Titanium has long been the gold standard, but increasing awareness of its biological and aesthetic limitations has stimulated interest in alternative materials, including zirconia and, more recently, polyetheretherketone (PEEK) [3,4].

Titanium dental implants

Titanium and its alloys are regarded as the gold standard materials for dental implants and implant abutments because of their excellent mechanical properties, outstanding corrosion resistance, and high biocompatibility with both bone and soft tissues [5]. The clinical success of Ti implants is primarily due to the spontaneous formation of a stable titanium dioxide (TiO_2) film, which improves corrosion resistance, protein adsorption, and cellular attachment, enabling predictable osseointegration [6].

In addition to osseointegration, the long-term success of an implant is also dependent on the formation of a stable peri-implant soft tissue seal. The peri-implant mucosa represents a biological barrier to protect the underlying bone from microbial invasion and inflammatory challenges. Hard and soft tissue integration are thus important for peri-implant health and long-term implant stability [2].

Despite their widespread success, titanium implants are not without limitations. Corrosion and tribocorrosion can lead to the release of titanium particles and ions, which have been linked to inflammatory responses in peri-implant tissues. Furthermore, the gray color of titanium may have a negative effect on the esthetic outcomes, especially in patients with a thin gingival phenotype or in highly esthetic regions. Such limitations have prompted the search for alternative implant materials and more advanced surface modification strategies [7-10].

Zirconia dental implants

Zirconia has become a promising metal-free alternative to titanium due to its good biocompatibility, excellent esthetic properties, and corrosion resistance. Its tooth-like appearance is particularly attractive in patients with a thin gingival phenotype or high esthetic demands. Surface-modified zirconia implants have also been reported to show improved osseointegration with bone-implant contact values similar to titanium implants [11-13].

Besides osseointegration, zirconia has shown a good soft tissue response. Similar or even better gingival fibroblast proliferation has been reported on zirconia surfaces compared to titanium, as well as reduced inflammatory cell infiltration and favorable connective tissue organization. These properties support its potential as a reliable implant and abutment material [14].

Despite these advantages, zirconia presents several limitations. Its inherent brittleness may increase the risk of fracture under high occlusal loads, especially in posterior regions. In addition, zirconia is susceptible to low-temperature degradation, which could affect the long-term mechanical properties [15,16]. Moreover, Morena., *et al*. [17] reported better survival rates and less marginal bone loss around titanium implants than zirconia, which indicates that there is a need for further improvements.

Polyetheretherketone (PEEK) dental implants

Regarding titanium's biological concerns and zirconia's mechanical limitations, polyetheretherketone (PEEK) has emerged as a polymer-based implant material capable of bridging these gaps. PEEK is a semi-crystalline thermoplastic polymer with an elastic modulus similar to the elastic modulus of cortical bone, compared to titanium. This biomechanical compatibility reduces stress shielding and encourages more physiological load distribution at the bone-implant interface [18].

Despite PEEK's favorable mechanical properties and biocompatibility, several systematic reviews and comparative studies indicate that unmodified PEEK exhibits a highly hydrophobic surface, thereby limiting soft tissue integration [19,20].

Surface modification strategies

The surface characteristics of dental implants play a critical role in determining the quality of tissue integration and long-term clinical success. Therefore, various surface modification strategies have been developed to improve the bioactivity of implants, to enhance protein adsorption, and to facilitate favorable cellular responses at the implant interface [20,21].

These strategies can be broadly classified as physical, chemical, and biological modifications. Physical methods such as sandblasting, acid etching, and laser treatment enhance surface roughness and cellular attachment. Chemical modifications, including anodization and plasma-based treatments, improve the surface wettability and biological activity. Hydroxyapatite and calcium phosphate coatings have been widely used to improve osseointegration by creating a more bioactive surface [21-23].

Platelet Concentrates: From PRP to PRF

To improve regenerative outcomes and to overcome the drawbacks of previous formulations, autologous platelet concentrates have been developed in successive generations. Platelet-rich plasma (PRP), the first-generation platelet concentrate, is a liquid formulation rich in growth factors such as transforming growth factor-beta (TGF-β), vascular endothelial growth factor (VEGF), and platelet-derived growth factor (PDGF). PRP has been extensively utilized in regenerative dentistry and has shown the potential to improve cellular responses when coating dental implant surfaces. However, its preparation requires anticoagulants, and its rapid release of growth factors may limit sustained biological activity [24-26].

To overcome these limitations, platelet-rich fibrin (PRF) was introduced as the second generation of platelet concentrate. PRP is prepared with anticoagulants, while PRF is prepared without anticoagulants and forms a fibrin matrix that allows for a slower and more sustained release of growth factors, thus better mimicking the natural wound healing process [27,28].

Gingival fibroblasts

Although much of the literature on platelet concentrates has focused on osseointegration and osteogenic responses, the soft tissue dimension is also very important. The main cellular component of the gingival connective tissue is the human gingival fibroblast, which is of key importance in the soft tissue seal that prevents microbial invasion of the peri-implant tissues. The adhesion, proliferation, and collagen synthesis of these cells are important determinants of peri-implant mucosal health and long-term implant stability [2,29]. Platelet concentrates have great potential for modulating the soft tissue environment around implants, apart from their well-characterized osteogenic effects, particularly in the use of a biologically inert surface.

Gingival mesenchymal stem cells and regeneration of tissue

Besides gingival fibroblasts, the gingival tissues are also comprised of a population of multipotent cells called the gingival mesenchymal stem cells (GMSCs), which possess self-renewal and multi-lineage differentiation potential [30,31]. Growth factors released from platelet concentrates, such as TGF-β and PDGF, can have a positive influence on GMSC behavior and regenerative potential [32]. Therefore, gingival fibroblasts are still the major cell type responsible for peri-implant soft tissue integration, but GMSCs may also have a role in the regenerative effect of the PRF-mediated tissue healing.

Conclusion

Current evidence indicates that platelet concentrates such as PRP or PRF are promising biofunctionalization approaches to improve the biological performance of dental implant surfaces. The long-term success of dental implants is not only dependent on osseointegration but also on a healthy peri-implant soft tissue seal that protects the underlying bone from microbial invasion and inflammatory challenges. Through the sustained release of growth factors and their positive effects on gingival fibroblast activity, platelet concentrates may help promote favorable soft tissue healing and integration around dental implants.

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