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METHODS FOR REDUCING THE DURATION OF OSSEOINTEGRATION IN DENTAL IMPLANTOLOGY

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Abstract
This article reviews practical methods to reduce osseointegration time in dental implantology: implant surface modifications (micro-roughness, hydrophilicity, bioactive coatings), biomaterial choices (titanium, zirconia, PEEK-based solutions), photobiomodulation (low-level laser therapy), and biological adjuncts (PRP/PRF, BMP-2, growth factors). Combined, these approaches may accelerate early bone formation, improve implant stability, and enable earlier functional loading. Key limitations include safety considerations, protocol standardization, and cost-effectiveness.

Keywords: Osseointegration; implant surface; hydrophilicity; laser therapy; PRP/PRF; BMP-2; titanium; zirconia.

Introduction

Osteointegration — the direct and stable connection of the implant surface with living bone — is a central requirement for the success of implantology. Traditional rehabilitation lasts 3–6 months: initial mechanical stability is gradually replaced by biological stability. Modern clinical practice aims to increase patient comfort, enable early prosthetics, and shorten the overall treatment cycle. Accordingly, in recent years, several approaches have been developed to reduce the duration of osteointegration: (1) physical-chemical modification of the implant surface; (2) optimization of biomaterial selection; (3) photobiomodulation; (4) biological growth factors and autologous preparations. The goal is to accelerate early bone formation, enhance implant stability, and allow for safe early loading.

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Material and methods

The article is based on a targeted analysis of the literature: clinical and preclinical studies, systematic reviews, and practical recommendations were compared. The focus was on: (a) methods to increase surface architecture and energy; (b) experiments with titanium–zirconium–PEEK materials; (c) laser/LED-based photobiomodulation protocols; (d) biological adjuncts such as PRP/PRF and BMP-2. Evaluation criteria included early-stage indicators (implant stability index, bone–implant contact percentage), timing of clinical loading, complications, and safety.

1) Implant surface modification Micro-roughness (SLA and similar methods): Sandblasting and acid etching create micro-architecture on the implant surface. This accelerates osteoblast adhesion and differentiation, increasing early bone–implant contact. As a result, the dynamics of stability during the healing phase are accelerated, and in some cases, the loading period can be reduced to a matter of weeks.

Hydrophilic surfaces: When the surface has high wettability and surface energy, blood clot formation spreads quickly and uniformly, protein adsorption is optimized, and cell migration is accelerated. Implants with hydrophilic surfaces are distinguished by early densification and rapid stability gain; clinical protocols are based on 6–8 week loading strategies [1].

Bioactive coatings (CaP, hydroxyapatite, etc.): Thin calcium-phosphate coatings can support chemical bonding and accelerate new bone formation. At the same time, coating stability and the risk of biofilm formation must be carefully managed.

Ionic/nano-modifications: Enriching the surface with additives such as fluoride, phosphate, or silver can enhance osteogenesis and antibacterial properties. This approach is promising, though clinical protocols are not yet fully established [2].

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2) Biomaterial Selection Titanium: The "gold standard." It has high biocompatibility, mechanical strength, and surface modifiability. Rough and/or hydrophilic titanium implants have the most evidence supporting early integration.

Zirconia: Offers significant advantages in aesthetic zones. With modern surface treatments, its osteointegration level approaches that of titanium. Long-term risk of fracture under load and limitations in prosthetic options should be considered. PEEK (coated solutions): Its elasticity is close to that of bone; however, the natural surface is inert and hydrophobic. Integration can be improved by coating with titanium or CaP and creating nano-structures. Currently, this is mostly at the experimental stage [3].

3) Photobiomodulation (low-level laser/LED): Laser/LED light stimulates mitochondrial activity, ATP synthesis, and angiogenesis, enhancing osteoblast activity. Practical outcomes include reduced pain and swelling, accelerated soft tissue healing, and improved early stability indicators. The effect is dose-dependent; clinical standards are evolving regarding wavelength, power density, and number of sessions.

4) Biological Approaches: PRP/PRF: Autologous platelet concentrates are rich in growth factors (PDGF, TGF-β, VEGF). The PRF membrane serves as a slow-release "reservoir." Clinical observations often show increased early bone density and stability. Variability in results depends on preparation method and concentration.

Discussion and Results

BMP-2 and other factors: Exhibit strong osteoinductive effects; when used with controlled-release technologies (nano-carriers, co-polymer matrices), they can significantly increase early BIC and densification. Safe dosing and cost-effectiveness are important considerations [4].

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Accelerating osteointegration is not limited to a single approach: surface architecture creates a "compatible" platform for bone cells; biomaterial choice determines mechanical and biological compatibility; photobiomodulation promotes post-surgical regeneration; biological agents specifically enhance osteogenesis.

The most reliable clinical strategy is a combination approach—for example, a hydrophilic-rough titanium implant + PRF membrane + standardized laser protocol.

Even so, three key limitations must always be considered:

Safety: Excessive bioactivity (e.g., high-dose BMP-2) may cause adverse reactions; bacterial biofilm risk must be controlled.

Standardization: Uniform parameter settings for laser, PRP/PRF, and coating protocols ensure stable results.

Economics: The cost of bioactive implants, laser sessions, and biological preparations must be balanced with patient benefit.

Practical Recommendations (Clinical Algorithm):

Pre-planning: Assess bone quality, general health, and periodontal status; choose implant based on early-loading goals.

Implant selection: Initially, hydrophilic-rough titanium (or zirconia with suitable surface in aesthetic zones).

Surgical technique: Atraumatic drilling, moderate insertion torque, achieve stable primary stability (ISQ monitoring).

Biological support: PRF membrane or selective PRP; consider additional support if bone quality is low.

PBM protocol: Several sessions of low-level laser/LED in the early phase (according to clinical standards).

Loading timing: Careful early loading within 6–8 weeks (or longer if necessary) based on individual ISQ and clinical signs.

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Conclusion

Scientific modification of the implant surface, optimal biomaterial selection, photobiomodulation, and biological agents can purposefully accelerate osteointegration. The most effective approach is an integrated, safe, and protocol-driven comprehensive strategy. This approach can, in many cases, reduce the rehabilitation cycle to a matter of weeks, increase patient comfort, and maintain stable clinical outcomes. In the future, extensive research is needed to standardize protocols and confirm cost-effectiveness with evidence.

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