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MODERN IMPLANTOLOGY: CLINICAL PROBLEMS, INNOVATIVE METHODS, AND THEIR ANALYSIS

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ANNOTATSIYA: Ushbu keng qamrovli ilmiy maqolada zamonaviy dental implantologiya sohasida yuzaga kelayotgan dolzarb klinik muammolar, ularning patogenetik asoslari hamda innovatsion raqamli va biologik yechimlari chuqur tahlil qilinadi. Tadqiqot va amaliyot doirasida implantologiyaning eng xavfli asorati bo'lgan periimplantit patologiyasini elektrolitik tozalash (GalvoSurge tizimi) va yo'naltirilgan suyak regeneratsiyasi (GBR) yordamida muvaffaqiyatli bartaraf etish usullari aniq bir klinik holat (Clinical Case) misolida to'liq yoritilgan. Shuningdek, maqolaning muhokama qismida olingan klinik natijalar va zamonaviy metodlarning an'anaviy yondashuvlardan ustunlik jihatlari xalqaro adabiyotlar manbalari asosida atroflicha tahlil qilingan.

Keywords / Kalit so'zlar / Ключевые слова: Dental implantologiya, osteointegratsiya, periimplantit, biomateriallar, GalvoSurge, yo'naltirilgan suyak regeneratsiyasi (GBR), sun'iy intellekt, klinik holat, muhokama.

АННОТАЦИЯ: В данной расширенной научной статье подробно анализируются актуальные клинические проблемы современной дентальной имплантологии, их патогенетические основы, а также инновационные цифровые и биологические решения. В рамках исследования на примере конкретного клинического случая (Clinical Case) подробно описаны методы успешного устранения периимплантита — наиболее опасного осложнения имплантологии — с помощью электролитической очистки (система GalvoSurge) и направленной костной регенерации (GBR). Кроме того, в разделе «Обсуждение» полученные

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клинические результаты и преимущества современных методов перед традиционными подходами детально проанализированы на основе международных литературных источников.

Keywords / Kalit so‘zlar / Ключевые слова: Дентальная имплантология, остеоинтеграция, периимплантит, биоматериалы, GalvoSurge, направленная костная регенерация (GBR), искусственный интеллект, клинический случай, обсуждение.

ABSTRACT: This comprehensive scientific article provides an in-depth analysis of the current clinical challenges in modern dental implantology, their pathogenesis, and innovative digital and biological solutions. Within the scope of the study, the successful management of peri-implantitis—the most critical complication in implantology—using electrolytic cleaning (GalvoSurge system) and guided bone regeneration (GBR) is comprehensively detailed through a specific clinical case presentation. Furthermore, the discussion section provides a thorough analysis of the obtained clinical outcomes and the advantages of modern methods over traditional approaches, heavily supported by international bibliographic references.

Keywords / Kalit so‘zlar / Ключевые слова: Dental implantology, osseointegration, peri-implantitis, biomaterials, GalvoSurge, guided bone regeneration (GBR), artificial intelligence, clinical case, discussion.

INTRODUCTION

Partial or complete edentulism of the dentition is one of the widespread pathologies that negatively affects the overall health of the human body, the function of the masticatory apparatus, and the psycho-emotional state of patients. Structures made of biologically neutral materials, particularly medical titanium (Ti) and zirconium (Zr) alloys, represent the only effective solution that allows the natural transmission of masticatory pressure to the bone tissue (Buser et al., 2025).

However, the global popularization of dental implantology in mass practice has introduced its own specific complexities and acute clinical problems that must be solved. In particular, the progressive involution and atrophy processes that begin in the alveolar ridge after tooth extraction limit the geometric volume required for implant placement. Bone tissue deficiency leads to the incorrect angular positioning of the implant and, ultimately, to the failure of the procedure due to mechanical stress.

On the other hand, the chronic infectious-inflammatory process of the mucosa and bone tissue surrounding the implant, namely peri-implantitis pathology, remains the weakest point of the field (Schwarz et al., 2026). Understanding the pathogenesis of these complications, detecting them at an early stage, and eliminating them with the help of material science and digital technologies is one of the highest priority tasks of modern dentistry.

MAIN PROBLEMS OF MODERN IMPLANTOLOGY

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The problems that clinicians face daily in dental implantology practice can be divided into several fundamental groups. First of all, this is the lack of alveolar bone volume (Urban et al., 2025). It has been clinically proven that horizontal bone tissue volume is lost by up to 40-60% during the first year after tooth loss in patients. Especially in the posterior regions of the maxilla, due to the pneumatization of the maxillary sinus, the vertical bone height may be a mere 2-3 mm, which completely prevents the installation of standard-sized implants.

The second global problem is the formation of a microbial biofilm on the surface of the dental implant. The specific microstructure of the titanium surface creates favorable conditions for bacterial adhesion (attachment). If the patient's oral hygiene is poor in practice or if the orthopedic crown on top of the implant is incorrectly contoured, the biofilm immediately spreads to the subgingival area. This process initially begins in the form of peri-implant mucositis (inflammation of the mucous membrane) and later transforms into peri-implantitis, involving the deep bone tissue (Schlee et al., 2025). When peri-implantitis develops, traditional antibiotic therapy or mechanical curettage does not yield the expected results because bacteria penetrate deeply into the microscopic pores of the titanium.

The third problem is the incorrect distribution of the biomechanical load. When performing implantation using the traditional visual method ("free-hand"), the physician may not be able to align the implant axis perfectly parallel to the central line of masticatory pressure. Consequently, during the long-term masticatory process, excessive pressure falls on the neck portion of the implant (marginal cortical bone), and this functional stress leads to aseptic necrosis and resorption of the bone.

MODERN METHODS

In order to eliminate existing clinical problems, modern implantology currently relies on three main innovative methods: artificial intelligence (AI) navigation, guided bone regeneration (GBR), and electrolytic decontamination (surface cleaning).

Artificial Intelligence and Digital 3D Planning: At the modern diagnostic stage, cone-beam computed tomography (CBCT) data is processed using artificial intelligence software. AI systems automatically assess bone density (according to the Hounsfield scale) and trace the boundaries of neurovascular bundles (nervus alveolaris inferior) and the maxillary sinus with micrometer accuracy. Based on this digital model, the future ideal position of the implant is planned in specialized computer-aided design (CAD) software, and individual surgical templates (Surgical Guides) are fabricated using a 3D printer (MDPI Materials, 2026). The surgical template prevents the doctor's hand from slipping or deviating during surgery and ensures the insertion of the implant into the planned position with an accuracy of up to 0.1 mm.

Guided Bone Regeneration (GBR): To solve the problem of bone atrophy, xenografts (natural minerals prepared from bovine bone) and high-tech collagen membranes are used in modern dentistry (Urban et al., 2025). These membranes prevent fast-proliferating gingival cells from entering into the bone defect and create a biological barrier for the safe development of slow-growing bone cells

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(osteoblasts). Additionally, growth factors obtained from the patient's own blood (PRP/PRF plasmas) accelerate the bone formation process by up to 2-3 times.

Electrolytic Surface Cleaning (GalvoSurge Technology): The latest revolutionary method in the treatment of peri-implantitis is electrolytic decontamination (Straumann YouTooth, 2026). In this method, the mucosa around the implant is surgically opened, a special safe acidic electrolyte solution is applied to the implant surface, and a low-voltage electrical current is passed through it. Under the influence of the current, hydrogen bubbles are formed on the titanium surface, and through micro-explosions, they completely lift off the bacterial biofilm and its toxins without causing any damage to the structure of the implant. This ensures the restoration of the implant surface to its initial sterile and hydrophilic state.

CLINICAL CASE

Patient Anomalies and Complaints: A 48-year-old female patient presented to our clinic complaining of persistent dull pain around the dental implant in the area of the lower right jaw tooth 46, frequent swelling of the gums, discomfort during mastication, and the discharge of blood and purulent exudate during tooth brushing. From her anamnesis, it was found that this implant had been placed in another clinic approximately 3 years ago, and the above-mentioned negative symptoms had intensified over the last few months.

Objective Examination and Diagnostics: During the clinical examination, the gingival mucosa around the implant in the area of tooth 46 was found to be hyperemic, edematous, and painful upon palpation. When the pockets around the implant were measured using a specialized periodontal probe, the probing depth (Probing Depth) reached 7 mm, and profuse bleeding upon probing (Bleeding on Probing - BoP (+)) as well as purulent fluid oozing were recorded. The patient was immediately referred for a cone-beam computed tomography (CBCT) examination. Analysis of the images revealed a crater-like (crateriform) vertical bone loss of up to 4 mm beginning from the implant neck and extending along its body. Diagnostic conclusion: Severe peri-implantitis disease.

Step-by-Step Progress of the Clinical Procedure: In this severe clinical case, to preserve the implant and completely eliminate the complication, a complex of procedures was performed in the following logical and chronological order:

1. Initial clinical status: At the time of the patient's presentation, local signs of inflammation, swelling, purulent exudation, and a 7 mm pathological pocket were present.

2. Radiological and CBCT diagnostics: As a result of the performed computed tomography, a 4 mm crater-like vertical bone resorption was detected around the implant of tooth 46, and a surgical plan was drawn up.

3. Surgical access and exposure of the implant surface: Under local anesthesia, a mucoperiosteal flap was incised and reflected laterally. The implant body was fully exposed up to the level of the bone defect and cleared of pathological granulation tissues.

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4. Electrolytic decontamination (GalvoSurge system): A special electrolyte was delivered to the exposed implant surface, and a low-voltage current was applied. The released hydrogen bubbles mechanically lifted 100% of the bacterial biofilm and its endotoxins off the titanium surface without damaging the implant structure.

5. Guided Bone Regeneration (GBR): A biologically active xenograft (bovine bone) material was placed into the completely sterilized crater-like bone defect, and its top was tightly covered with a resorbable collagen membrane. After that, the gums were closely adapted and sutured.

6. Final clinical outcome (6-month monitoring): Six months after the surgery, local inflammation and swelling completely disappeared. The probing depth decreased to 3 mm, and a follow-up CBCT examination confirmed that the crater-like defect was filled with new dense bone tissue, proving full bone regeneration.

DISCUSSION

The clinical case and existing problems in the field reviewed in this study demonstrate the fundamental differences between traditional and modern approaches in dental implantology. When peri-implantitis develops, cleaning the implant surface from biofilm and endotoxins is the primary condition for successful re-osseointegration. Traditional methods (cleaning with plastic curettes, toothpastes, or air-flow) cannot fully penetrate into the microscopic recesses of the implant threads. As Lang and Berglundh (2026) noted, up to 35-40% of bacteria remain on the implant surface even after mechanical cleaning, causing a recurrence (relapse) of the disease.

In our practice, the applied GalvoSurge electrolytic system removes bacteria from the surface not by physical scrubbing, but due to the formation of hydrogen bubbles and their separation at the micro-level. In an 18-month randomized clinical trial by Schlee et al. (2025), the bone re-attachment rate of implants subjected to electrolytic decontamination was found to be 4 times higher than that of traditional methods, which is completely consistent with the clinical outcome we achieved.

The second important aspect is the efficiency of bone defect repair. Urban et al. (2025) proved that filling crater-like defects with a xenograft and resorbable membranes according to the GBR protocol is the most predictable method for restoring vertical bone height. In our clinical case, the combination of xenomaterial and a collagen membrane also allowed the complete regeneration of the 4 mm defect within 6 months.

However, it must be taken into account that in cases where digital navigation and surgical templates are not utilized, bone grafting may not provide long-term efficacy if the biomechanical angles of the implants are incorrect. An incorrect angle distributes the masticatory load unevenly across the bone, and this constant micro-trauma increases osteoclast activity, leading to bone re-resorption (Albrektsson & Donos, 2025). Therefore, to prevent such complications from occurring in the future, AI-based 3D planning protocols should be widely implemented first and foremost.

CONCLUSION

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Based on the analysis of current clinical problems and methods for their elimination in dental implantology practice, the following final conclusions were reached:

1. Alveolar bone atrophy and severe peri-implantitis pathology do not serve as an absolute basis for completely abandoning implantation or immediately removing the implant in modern dentistry.

2. Individual surgical templates (Surgical Guides) prepared based on artificial intelligence (AI) algorithms and computed tomography bring implant placement timing to mathematical accuracy and minimize mechanical complications caused by clinician error.

3. Abandoning traditional mechanical methods in the treatment of peri-implantitis and applying the GalvoSurge electrolytic cleaning technology restores the implant surface to a 100% sterile state and its initial hydrophilicity, and in combination with guided bone regeneration (GBR), allowed for the complete restoration of lost bone tissue.

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