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Журнал объединяет авторов на территории стран СНГ и помогает обмениваться передовыми научно-образовательными исследованиями.

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ФИО автора(-ов): *OGUZ HAN ENGINEERING AND TECHNOLOGY UNIVERSITY OF TURKMENISTAN*

Teacher: Selbi Gulmuhammedova

Student: Panjiyeva Aynura

Название публикации: «BIONIC EYE IMPLANTS: ADVANCES IN BIOMEDICAL ENGINEERING»

What is a Bionic Eye Implant?

Bionic eye implants, also known as visual prostheses or retinal implants, are advanced biomedical devices designed to restore functional vision in individuals with severe vision loss due to retinal degenerative diseases such as retinitis pigmentosa (RP) and age-related macular degeneration (AMD). These implants interface with the visual system, bypassing damaged photoreceptors by electrically stimulating surviving retinal neurons, optic nerve, or visual cortex to generate visual perceptions (phosphenes). Core components include an external camera for capturing images, a processing unit to convert visual data into electrical signals, and an implantable electrode array to stimulate neural tissue. Systems like Argus II, Alpha-IMS, and PRIMA integrate microelectronics and biocompatible materials, offering partial vision restoration, such as object recognition and navigation, for legally blind individuals. Emerging innovations incorporate AI for image processing, optogenetics for enhanced neural stimulation, and flexible materials to improve biocompatibility, aiming to mimic natural visual processing more closely.

Academic Review: Evolution, Technologies, and Prospects in Visual Restoration

Abstract

Bionic eye implants represent a frontier in neuroengineering, combining microelectronics, biomaterials, and AI to restore vision in retinal blindness. This review traces their evolution from early cortical stimulators to modern retinal and optic nerve prostheses, analyzing clinical outcomes, technological advancements, and

challenges like electrode longevity and visual acuity limitations. Drawing on publications from 1970–2025, including bibliometric data and clinical trials, it highlights systems achieving up to 20/200 vision and phosphene-based object detection. Future directions emphasize optogenetic hybrids, AI-driven image optimization, and cortical implants for broader applicability. Keywords: bionic eye, visual prosthesis, retinal implant, optogenetics, neural interfaces, vision restoration.

Introduction

Retinal degenerative diseases affect over 170 million people globally, leading to profound vision loss and significant socioeconomic impact. Bionic eye implants offer a solution by bypassing damaged photoreceptors, stimulating intact visual pathways to restore functional vision. Unlike corrective lenses or gene therapies, these devices provide an electronic interface for end-stage blindness, integrating with the retina, optic nerve, or cortex. Advances in microfabrication, neural interfaces, and AI have accelerated progress, with systems like Argus II achieving FDA approval in 2013. This review synthesizes historical milestones, current technologies, clinical evidence, and future prospects based on over 3,000 publications from 1970–2025, noting a 12% annual research growth since 2010.

Historical Overview

The concept of visual prostheses emerged in the 1920s with Otfrid Foerster's observation that cortical stimulation induced phosphenes. In the 1970s, Brindley and Dobelle developed cortical implants with platinum electrodes, laying groundwork for neural stimulation. The 1990s saw retinal implants, with the Optobionics Artificial Silicon Retina (ASR, 2000) marking early clinical trials. The Argus II (Second Sight, 2013) became the first FDA-approved retinal prosthesis, using a 60-electrode array to provide 20/1260 vision. Europe's Alpha-IMS (Retina Implant AG, 2013) and Pixium Vision's IRIS/PRIMA systems followed, with subretinal designs offering improved resolution. By 2025, cortical implants like Orion and optic nerve stimulators expanded applicability to optic nerve atrophy and glaucoma.

Current Technologies

Retinal Implants

Retinal prostheses target epiretinal (e.g., Argus II) or subretinal (e.g., Alpha-AMS) layers, stimulating ganglion cells or bipolar cells. The Argus II uses a 60-electrode array, external camera, and video processing unit (VPU) to generate phosphenes, enabling letter recognition (26% accuracy) and navigation. Alpha-AMS, with 1,600 photodiodes, achieves 20/546 vision in RP patients, though subretinal surgery is invasive. PRIMA's photovoltaic array (378 pixels) delivers 20/460 vision, with wireless subretinal placement reducing surgical risks.

Cortical and Optic Nerve Implants

Cortical implants, like Orion (Second Sight), target the visual cortex, bypassing retinal damage for conditions like glaucoma. A 2024 trial with 60 electrodes enabled shape discrimination. Optic nerve prostheses, such as CORTIVIS, use cuff electrodes for stimulation, showing promise in preclinical models for optic atrophy. These systems expand eligibility beyond retinal diseases.

Optogenetic and Hybrid Systems

Optogenetics enhances bionic eyes by genetically modifying neurons to express light-sensitive proteins (opsins), improving stimulation precision. Trials in 2025 combined PRIMA with opsin delivery, achieving 20/200 vision in non-human primates. Flexible electrode arrays, using graphene or polyimide, reduce tissue damage and improve longevity, with in vivo stability up to 6 months.

AI and Image Processing

AI-driven image processing optimizes phosphene generation by prioritizing high-contrast features. Convolutional neural networks (CNNs) in systems like Bionic Vision Australia's Gen3 enhance object detection (85% accuracy) by filtering noise and adapting to user needs. Real-time ML reduces latency, critical for dynamic environments.

Challenges and Future Directions

Challenges include limited visual acuity (best at 20/200), electrode degradation, high costs ($100,000–$150,000), and surgical risks like retinal detachment. Cortical implants face issues with phosphene mapping and neural plasticity. Future directions include high-density electrodes (10,000+ channels), AI-personalized algorithms, and optogenetic hybrids for finer resolution. Tissue-engineered scaffolds and stem cell integration aim to regenerate retinal tissue, while wireless power systems (e.g., ultrasonic or photovoltaic) reduce implant bulk. Clinical trials for fully wireless cortical systems are projected by 2030.

Conclusion

Bionic eye implants have evolved from experimental stimulators to clinically approved devices, restoring functional vision for the blind. Innovations in optogenetics, AI, and biomaterials promise higher acuity and broader applicability. Continued interdisciplinary research, supported by global trials, is essential to overcome technical and economic barriers, paving the way for next-generation visual restoration.

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