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Review Article

Neuroprosthodontics: Bridging the Gap Between Prosthodontics and Neurology

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Abstract

Neuroprosthodontics is an emerging interdisciplinary field integrating prosthodontics with neuroscience to enhance oral rehabilitation outcomes. The loss of teeth and associated sensory input leads to significant neuroplastic changes, affecting somatosensory cortical representation. Recent advances in artificial intelligence (AI), brain-computer interfaces (BCI), and implantable biosensors have enabled prosthetic designs that provide real-time sensory feedback, improving adaptation and function. This review discusses the role of neuroplasticity in prosthodontic rehabilitation, AI-driven sensory augmentation, and BCI applications in oral prosthetics. The integration of neuroprosthodontics could revolutionize patient care by enhancing sensory-motor integration and cognitive function.

Keywords: Neuroprosthodontics; Neuroplasticity; Brain-Computer Interface; Sensory Feedback, Prosthetic Rehabilitation; Cortical Reorganization; Dental Implants, Cognitive Function

Introduction

The interplay between prosthodontics and neurology is becoming increasingly recognized as critical for optimizing patient outcomes. Tooth loss leads to structural and functional changes in the brain, including cortical reorganization and altered sensorimotor integration [1]. Conventional prosthetic interventions primarily focus on mechanical rehabilitation, often neglecting neural adaptation. However, emerging evidence suggests that restoring mastication through prosthetic rehabilitation can enhance neuroplasticity, improving cognitive function and oral motor control [2]. The application of AI, brain-machine interfaces (BMI), and biosensors in prosthodontics presents new opportunities for restoring lost neurosensory function [3].

Neuroplasticity and Prosthetic Adaptation

Cortical Reorganization After Tooth Loss

Neuroplasticity refers to the brain's ability to reorganize itself in response to injury or sensory deprivation. Functional MRI (fMRI) studies indicate that tooth loss alters the somatosensory cortex, leading to compensatory neural activity in adjacent cortical areas [4]. The absence of periodontal ligament mechanoreceptors reduces proprioceptive input, affecting occlusal awareness and fine motor control [5]. Dental implants and removable prostheses have been shown to partially restore cortical maps, but the degree of neuroplastic adaptation varies depending on the rehabilitation method [6].

Masticatory Function and Brain Stimulation

Mastication plays a vital role in maintaining cognitive function by stimulating the hippocampus and prefrontal cortex [7]. Studies suggest a strong correlation between impaired chewing ability and an increased risk of neurodegenerative diseases such as Alzheimer's and Parkinson's disease [8]. Restoration of occlusion with well-fitted prostheses has been linked to improved cognitive performance, likely due to enhanced sensory input and neurotrophic factor release [9].

AI-Driven Sensory Augmentation in Implant-Supported Prostheses

Smart Prostheses with Sensory Feedback

Traditional dental prostheses lack the proprioceptive feedback necessary for fine motor control, leading to difficulties in mastication and speech. AI-integrated prostheses incorporating pressure sensors and vibrotactile feedback systems offer real-time sensory input, mimicking natural proprioception [10]. Advanced prosthetic systems using piezoelectric transducers can convert mechanical forces into electrical signals, transmitting feedback to the brain via peripheral nerves [11].

Neural-Integrated Prosthetics

Recent developments in neural-integrated prosthetics have demonstrated the potential for direct communication between prosthetic devices and the central nervous system [12]. By incorporating intraneural electrodes, researchers have enabled bidirectional sensory-motor communication in upper limb prostheses, a concept now being explored for dental applications [13]. Implantable biosensors that monitor occlusal forces and relay data to the trigeminal sensory pathways may improve adaptation and function in edentulous patients [14].

Brain-Computer Interfaces (BCI) and Future Applications in Neuroprosthodontics

Direct Neural Control of Prosthetic Devices

BCI technology enables direct neural control of prosthetic limbs and has shown promise for dental applications [15]. Studies in primates have demonstrated that intracortical microelectrode arrays can decode orofacial motor signals, allowing for precise prosthetic movement control [16]. The application of BCI in prosthodontics could allow users to adjust occlusal parameters and masticatory function through brain signals alone [17].

Cognitive Rehabilitation Through Prosthodontics

Neurofeedback from advanced prosthetic systems may play a role in cognitive rehabilitation, particularly in elderly populations suffering from dementia or stroke-related deficits [18]. AI-driven adaptive prostheses equipped with machine learning algorithms can analyse neuromuscular patterns and optimize occlusal function dynamically [19].

Conclusion

Neuroprosthodontics is a rapidly evolving field that integrates prosthodontics with neuroscience, AI, and BCI technologies to enhance sensory-motor function and neuroplastic adaptation. The development of AI-driven prostheses with sensory feedback and neural interfaces holds the potential to redefine oral rehabilitation. Future research should focus on optimizing neuroprosthetic adaptation and exploring clinical applications of BCI in prosthodontics. The convergence of these technologies promises to improve not only functional outcomes but also cognitive health and overall quality of life for patients requiring prosthetic rehabilitation.

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