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NEUROPLASTICITY INSIGHTS IN PROSTHODONTICS– FROM EDENTULUSIM TO CORTICAL REORGANIZATION

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Abstract

Neuroplasticity has become increasingly relevant in understanding how the brain adapts to prosthodontic rehabilitation. This narrative review examines current evidence on how dentures, implant-supported prostheses, and occlusal splints influence cortical reorganization and the restoration of sensory–motor function. A literature search of studies published between 2008 and 2025 was conducted through PubMed and MEDLINE, with supporting evidence obtained frompeer-reviewed publications outside these databases. Findings show that oral rehabilitation reactivates somatosensory and motor cortices, improving mastication, proprioception, and functional control, with particularly significant benefits in elderly patients. Conversely, maladaptive plasticity contributes to temporomandibular disorders, which can be modified through occlusal stabilization and neuromuscular therapies. Emerging innovationssuch as digital prostheses, neuromuscular stimulation, and sensor-based systems, further support adaptive cortical change. Understanding these neural mechanisms broadens the prosthodontic perspective, highlighting that successful rehabilitation restores both oral structures and the brain's capacity to relearn function.

Keywords: neuroplasticity, corticalreorganization, osseoperception, neural adaptation, oral rehabilitation

Introduction

Prosthodontics focuses on restoring oral function, appearance, and patient comfort through the replacement of missing teeth and surrounding structures. Its purpose extends beyond mechanical reconstruction and it seeks to reestablish neuromuscular harmony and sensory perception within the masticatory system. Tooth loss disrupts the complex network of proprioceptive feedback from the periodontal ligament, oral mucosa, and masticatory muscles, leading to altered bite control, reduced masticatory efficiency, and even changes in cortical processing related to oral function. Neuroplasticity, defined as the brain's ability to reorganize its structure and function in response to sensory and functional stimuli, plays a key role in adapting to these changes. Once believed to occur only in childhood, studies have now established that the adult brain retains a remarkable capacity for structural and functional remodeling, enabling recovery of lost or altered functions[1]. Early thinkers such as William James and Jerzy Konorski introduced the concept of neural adaptability, which has since been validated through modern imaging and neurophysiological research. In prosthodontics, this adaptability manifests as cortical reorganization following denture or implant rehabilitation, where neuroimaging studies demonstrate reactivation of the primary motor and somatosensory cortices after prosthesis use[2]. These neural adjustments contribute to improved coordination, proprioception, and masticatory control. The concept of neuroplastic prosthodontics has therefore emerged, emphasizing that prosthetic treatment is not merely a structural replacement but a process of neurosensory training. Repeated sensory-motor activities such as chewing, occlusal contact, and proprioceptive feedback reinforce neural pathways, enhancing adaptation and long-term oral function.[1,2]

Concept of neuroplasticity and cortical plasticity

Neuroplasticity is the brain's intrinsic ability to reorganize its structure and function in response to sensory alterations, motor demands, or injury. It enables the nervous system to form new synaptic connections and reorganize existing neural pathways to maintain or recover lost function. In prosthodontics, this adaptability is of particular significance, as tooth loss and subsequent prosthetic rehabilitation alter oral sensory feedback and motor coordination, requiring the brain to relearn and refine patterns of mastication and proprioception. Two principal types of neuroplasticity are recognized: structural plasticity, involving physical changes in dendritic connections and synapse formation, and functional plasticity, which reflects variations in neural activity and synaptic efficiency within established circuits. These complementary processes enable the cortex to adapt continuously to changing peripheral inputs.[2,3]

Cortical plasticity, a subset of neuroplasticity, occurs when the cortical representation of a body part changes following sensory or motor modification. Loss of natural teeth reduces activity in cortical regions responsible for oral sensation and motor control. Studies using functional magnetic resonance imaging (fMRI) have shown that rehabilitation with dentures or implant-supported prostheses restores and enhances activity within the primary motor and somatosensory cortices through mechanisms of cortical remapping and increased regional cerebral blood flow. Such cortical reorganization supports improvements in masticatory efficiency, bite control, and oral perception, highlighting the neural basis of functional recovery in prosthodontic treatment.[4]

Oral rehabilitation and brain function

Tooth loss and reduced mastication profoundly affect both oral and cognitive functions, particularly in elderly individuals. Edentulism leads to decreased sensory input from periodontal and oral mechanoreceptors, resulting in reduced stimulation of the somatosensory and motor cortices[5]. This deprivation can cause cortical reorganization and diminished activity in brain regions responsible for memory, attention, and coordination. The loss of afferent signals from the masticatory system, termed deafferentation, alters neural integration between the oral cavity and the central nervous system, which may contribute to cognitive decline and reduced motor precision[6]. In older adults, edentulism has been strongly associated with a higher risk of dementia and Alzheimer's disease. Studies have shown that reduced chewing activity lowers cerebral blood flow and oxygenation in the prefrontal cortex and hippocampusregions which are vital for memory and executive function. This relationship supports the emerging concept of a brain–stomatognathic axis, which describes the close neural connection between mastication and brain performance. Chronic loss of oral input accelerates hippocampal degeneration and impairs cognitive processing in contrast to restoring masticatory function which may reverse or mitigate these effects.[7]

Oral rehabilitation through dentures or implant-supported prostheses has demonstrated measurable improvement in brain function. Functional MRI studies show that mastication with dentures reactivates the prefrontal cortex and hippocampus, enhancing cognitive tasks related to attention and recall. Implant-retained overdentures, in particular, produce stronger cortical responses and higher Mini-Mental State Examination (MMSE) scores than conventional complete dentures, suggesting superior sensory feedback and cortical stimulation[6]. Another clinical study also reported that rehabilitation of masticatory function in older adults led to significant improvement in episodic memory and executive performance over one year of follow-up[7]. These findings emphasises the concept that oral rehabilitation is not solely a mechanical restoration but a neurosensory reactivation process, by reinstating sensory feedback, occlusal stability, and masticatory rhythm where theprosthodontic treatment can stimulate cortical reorganization and supports cognitive health. Restoring masticatory efficiency can therefore be considered a modifiable factor in preserving brain function, particularly in populations at risk of age-related cognitive decline.(5,8)

Neural adaptation to Prosthodontic treatment

The process of adaptation following prosthodontic treatment demonstrates the brain's ability to reorganize in response to altered sensory and motor inputs from the oral cavity. Tooth loss leads to reduced afferent stimulation from periodontal and oral mechanoreceptors, while prosthetic replacement restores this input through alternate feedback mechanisms. These neural adjustments are central to functional rehabilitation and are supported by both electrophysiological and neuroimaging evidence.[1]

• Role of Complete and Removable Dentures in Restoring Somatosensory Feedback

Complete and removable dentures reintroduce occlusal stimuli that re-engage sensory and motor pathways within the stomatognathic system. Hosoi et al. (2011) demonstrated through electroencephalography (EEG) that denture treatment significantly increased occlusal contact area, bite force, and cortical activation, particularly within the prefrontal and sensorimotor regions[9]. Similarly, Narita et al. (2009) reported that mastication with newly fitted dentures increased regional cerebral blood flow in the dorsolateral prefrontal cortex, reflecting functional recovery of sensorimotor and cognitive pathways approximately 2–3 months after prosthesis use. These results suggest that prosthodontic treatment improves not only chewing ability but also re-establishes the somatosensory feedback needed for coordinated oral motor control.(10)

• Functional MRI and EEG Evidence

Functional MRI studies show strong evidence of cortical adaptation during denture rehabilitation. Luraschi et al. (2013) reported that denture replacement increased activation in the precentral and postcentral gyri, demonstrating greater involvement of the brain's primary motor and sensory regions during clenching and chewing. This activity continued to improve over the first three months and matched the clinical gains seen in chewing efficiency and bite force.[1] Hosoi et al. (2011) also noted that EEG recordings became more synchronized after prosthesis insertion, indicating that the cortical networks responsible for jaw and facial movements were reorganizing in response to treatment.[9] In patients wearing implant-retained overdentures, Padmanabhan et al. (2022) observed the most significant cortical improvements between three and six months. This was supported by stronger fMRI responses and parallel improvements in MMSE scores, reflecting both functional and cognitive benefits.[6]

- **Osseoperception and Implants**

Inpatients rehabilitated with implants, sensory feedback is achieved through osseoperception, which is the capacity to perceive tactile and proprioceptive stimuli via peri-implant mechanoreceptors despite the absence of periodontal ligaments. Osseoperception involves mechanoreception through bone, periosteum, mucosa, and masticatory muscle receptors that transmit signals to the central nervous system[11]. Functional imaging studies confirm that implant-supported prostheses activate cortical regions similar to those engaged by natural teeth. Chen et al. (2008) found elevatedblood-oxygen-level-dependent (BOLD) responses in the primary sensorimotor cortex, prefrontal cortex, hippocampus, and supplementary motor areas following implant-supported denture use. These neural changes indicate that cortical adaptation

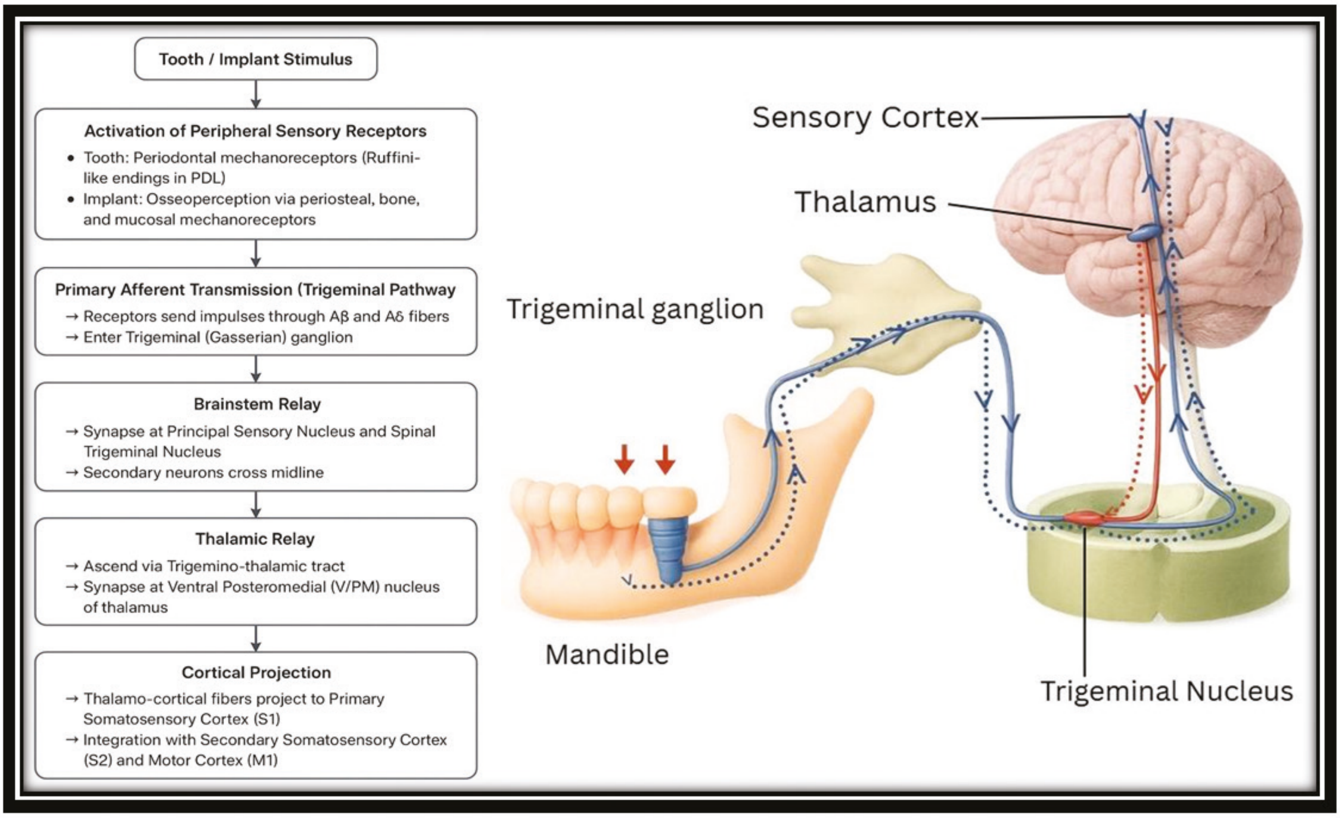

Figure 1: Sensory Pathway – From Tooth / Implant Stimuli to Cortical Processing

and improved processing develop within roughly 12 weeks.[12] Song et al. (2021) further established through systematic review that peri-implant mechanoreceptors generate sensory input contributing to tactile perception and fine occlusal control, mediated through cortical plasticity and trigeminal sensory pathways[11]. This neuroadaptive mechanism allows implants to functionally integrate into the body's sensory system, providing refined oral control and stability.

Mechanotransduction forms the basis of osseoperception by converting mechanical loading on implants into neural signals. Peri-implant bone deformation stimulates mechanosensitive nerve endings within the periosteum and bone matrix, transmitting afferent impulses via the trigeminal pathway to the brainstem, thalamus, and ultimately the primary and secondary somatosensory cortices (S1, S2) and motor cortex (M1). Functional imaging supports that these signals modulate cortical excitability, enabling adaptive refinement of bite force and mastication precision over time. The sensory pathway for both natural teeth and implants is summarized in Figure 1, highlighting the transformation from peripheral mechanoreception to cortical projection through trigeminal relay mechanisms and the functional outcome is perception of tactile pressure, force, proprioception and modulation of masticatory control, bite force, and adaptation of prosthesis.[11,12]

- **Changes in Motor Control, Bite Force, andNeurophysiological Adaptation**

Motor adaptation following prosthodontic rehabilitation is marked by progressive improvement in masticatory control, bite strength, and neuromuscular coordination. Luraschi et al. (2013) demonstrated that maximum bite force and chewing efficiency increased significantly within weeks afterdenture insertion, reaching near-optimal levels within three months as cortical activation patterns stabilized[1]. These gains reflect enhanced coordination between sensory and motor pathways and reduced variability in jaw movement. Chakraborty and Mukherjee et al. (2021) described this adaptation as evidence of both functional and structural neuroplasticity, where repeated prosthesis use reinforces neural circuits responsible for oral motor control. Functional MRI and EEG findings further support that this adaptation phase represents a distinct learning process: as patients become accustomed to their prostheses, sensorimotor networks show progressive reactivation consistent with Hebbian learning principles, in which repeated sensory–motor engagement strengthens synaptic connections and stabilizes cortical representations of the oral cavity[13]. Adaptation occurs progressively, with early neural changes emerging by three to four weeks and more stable sensory–motor integration typically developing by three to six months, reflecting the staged nature of neuroplastic recovery. Together, these findings confirm that prosthodontic rehabilitation induces measurable neurophysiological re-education, aligning peripheral sensory restoration with central motor control.

Neuroplasticity in temporomandibular disorders (TMD)

Temporomandibular disorders (TMD) reflect maladaptive neuroplasticity, where persistent nociceptive input from the joint and masticatory muscles alters cortical organization and motor control. Repeated pain input strengthens maladaptive neural pathways, causing the brain to "learn" dysfunctional patterns that maintain pain, muscle overactivity, and altered jaw movements even after the original cause has resolved. Functional MRI and EEG studies show hyperactivation of the primary somatosensory and motor cortices and increased limbic activity, consistent with central sensitization[14].

Prolonged TMD disrupts precise cortical maps of jaw musculature, impairing coordination and bite regulation[5]. Disturbed occlusal and proprioceptive feedback further modifies cerebral blood flow and cortical activity, similar to neural adaptation seen after oral rehabilitation.[6]

Occlusal splints act as a neurophysiologic stabilizer by re-establishing balanced sensory input and reducing abnormal muscle activity. Splint therapy modulates trigeminal afferents, restores cortical symmetry, and promotes normalization of sensorimotor activation.[14] When combined with physiotherapy or biofeedback, these interventions utilize adaptive plasticity to reduce pain and re-establish coordinated motor control.

Innovative Technologies

Neuromuscular Training and Digital Rehabilitation

Neuromuscular stimulation and targeted masticatory exercises have been shown to enhance cortical adaptation after prosthodontic treatment. EMG-guided training, biofeedback, and repetitive chewing routines improve trigeminal–motor coordination and shorten the learning phase for new dentures or implants. Sylvana A M (2024) reported that neuromuscular stimulation devices strengthen facial and masticatory muscle activity, supporting cortical reorganization and faster prosthetic adaptation. Parallel progress in digital denture design, especially CAD/CAM fabrication, provides precise occlusal balance and fit, minimizing irregular sensory input and promoting stable cortical mapping during rehabilitation.[15]

Smart Prostheses and Neuro-Integrated Technologies

Advances in sensor-embedded and AI-assisted prostheses are redefining oral rehabilitation. Pandey et al. (2025) described implant systems with intraoral pressure sensors capable of delivering tactile feedback that mimics periodontal sensation, facilitating cortical remapping and improved proprioception. These smartprostheses use adaptive AI algorithms to analyzeocclusal force and mastication rhythm in real time, guiding patient-specific training and optimizing neural adaptation. Future neuro-integrated interfaces and braincomputer communication models hold potential for bidirectional exchange between prostheses and the central nervous system, enabling voluntary modulation of bite force and occlusal precision.[16]

Discussion

Neuroplasticity provides the biological basis for how prosthodontic treatment restores function after tooth loss. Edentulism disrupts afferent input from periodontal and oral mechanoreceptors, producing cortical reorganization and reduced sensorimotor precision. Oral rehabilitation, whether through complete dentures or implant-supported prosthesisreactivates the somatosensory and motor cortices, improving masticatory coordination, bite force, and proprioceptive awareness[9,10]. Functional imaging confirms that cortical activation increases as patients adapt to new prostheses, showing that rehabilitation is a neurobiological as well as mechanical process[1]. In older adults, oral rehabilitation contributes not only to chewing efficiency but also to cognitive maintenance. Reduced mastication in the elderly has been linked to diminished hippocampal activity and accelerated cognitive decline. Re-establishing masticatory function through well-adapted prostheses restores cerebral perfusion and promotes activation of prefrontal and hippocampal areas[6,17]. These effects demonstrate that prosthodontic care in the elderly promotes both oral and neural health, limiting age-associated cortical regression.

Implant rehabilitation offers further neuroplastic benefit through osseoperception where mechanical signals are transmitted via bone and periosteal mechanoreceptors that evoke tactile feedback closely resembling to natural dentition. Functional MRI studies demonstrate progressive normalization of cortical activity following implant loading, suggesting sensory substitution and new pathway formation. Mechanotransduction at the implant interface therefore contributes directly to cortical re-adaptation.[11,12]

Conversely, temporomandibular disorders (TMD) illustrate maladaptive neuroplasticity. Persistent nociceptive input induces cortical hyperexcitability and disorganized motor control, reinforcing pain cycles[14]. Occlusal splints and physiotherapy correct these maladaptive circuits by stabilizing occlusal input and restoring symmetrical sensorimotor activation. Similar adaptive responses have been observed in patients with neuromuscular disorders such as Parkinson's disease, where rehabilitative prostheses improve oral motor coordination and cortical responsiveness.[5,17]

Prosthodontics is entering an era where rehabilitation is viewed as guided cortical retraining rather than mere structural replacement. Approaches such as neuromuscular stimulation, EMG-guided exercises, and digitally fabricated prostheses promote adaptive cortical responses and can shorten the overall adaptation period for patients. The integration of AI and sensor-embedded prostheses further enhances feedback precision, simulating lost periodontal sensation and allowing real-time monitoring of occlusal balance and mastication. These advances define the emerging field of neuroplastic prosthodontics, which merges neuroscience, digital design, and artificial intelligence to support complete functional rehabilitation.[15,16]

Across current evidence, prosthodontic rehabilitation can be viewed as a form of guided neural re-education, where adaptive neuroplasticity helps restore sensory–motor balance and disrupted inputs contribute to dysfunction. In older adults, improved mastication supports cortical activity and cognitive stability while in patients with TMD, restoring stable occlusal input helps reverse maladaptive neural patterns; and in implant therapy, osseoperception re-establishes a sensory connection between the implant and the body's natural feedback pathways. With ongoing advances in digital design, neuromuscular training, and AI-based feedback systems, neuroplastic prosthodontics now aims not only to replace lost oral structures but also to restore the brain's capacity to control and coordinate oral function.

Conclusion

Prosthodontic treatment restores more than missing teeth where it helps the brain relearn how to control oral functions through neuroplastic responses triggered by dentures, implants, and splints which improve sensory–motor coordination and mastication. Understanding this neural aspect, especially in elderly individuals and patients with TMD, reinforces that successful rehabilitation depends on re-establishing a healthy relationship between the prosthesis and the brain.

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