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Effect of prosthetic Rehabilitation on Neuroplasticity

Dr. Aarzoo Pathak[1], Dr. Rekha Gupta[2*], Dr. Shubhra Gill[2], Dr. Swarnim Singh[1], Dr. Meshi Longd[1]
[1] Department of Prosthodontics, Crown and Bridge, Maulana Azad Institute of Dental Sciences, New Delhi, India
[2] Professor, Department of Prosthodontics, Crown and Bridge, Maulana Azad Institute of Dental Sciences, New Delhi, India

Abstract
Masticatory function is a crucial component of oral health, and oral rehabilitation should focus on preserving or restoring proper function. The effectiveness of prosthodontic treatment depends on how well patients can adapt to a changed oral environment that includes the prosthesis indicated. The aim of this review is to provide an insight into neuroplastic changes in the brain due to various modalities of prosthetic treatment and facilitate a better understanding of neurological pathways involved when changes in stimulus are presented to the stomatognathic system.

Keywords: Neuroplasticity, prosthodontics, rehabilitation, brain activity

Introduction

Cognitive decline is a natural and universal element of aging. Memory loss typically becomes noticeable in many older adults, with the decline potentially starting around age 30 and gradually worsening over time. Furthermore, nearly all older individuals eventually experience a decrease in processing speed.

Normal cognitive decline is different from pathological cognitive loss, which affects a significant portion of older adults and can lead to dementia. In the early stages, pathological cognitive decline may appear similar to typical aging, but it often progresses to a sharp decline in functioning, particularly in memory. About 25% of older adults will develop mild cognitive impairment (MCI), characterized by noticeable difficulties in specific cognitive areas like memory, while daily living activities generally remain unaffected. People with MCI experience severe reductions in neuromodulatory activity, which is critical for sustaining learning and memory functions [1].

Brain plasticity, also known as neuroplasticity, refers to the brain's lifelong ability to physically and functionally change. This adaptability explains how experiences lead to learning throughout our lives. The concept of brain plasticity has been around for over a century, and its exploration has been active for several decades [2]. This principle underscores the brain’s dynamic nature, allowing it to reorganize itself through new neural connections in response to learning, experience, and environmental factors.

Tooth loss remains a significant dental health concern because it can lead to reduced chewing efficiency and bite strength, speech problems, and possibly even negative effects on cognitive function and memory [3]. It can greatly impact food selection and consumption, potentially leading to insufficient nutrient intake. Dental caries and periodontal disease are the most frequent causes of tooth loss. Studies have also found links between tooth loss and changes in brain structure. For example, individuals who are completely edentulous have significant gray matter atrophy in the right hippocampus and caudate compared to those with at least 20 teeth. Among people with cognitive impairments, a greater number of missing teeth is associated with reduced gray matter volume in areas such as the bilateral primary motor cortex, premotor cortex, left hippocampus, and parahippocampal region. Conversely, in elderly individuals without cognitive impairments, a higher gray matter volume in the premotor cortex is positively associated with having more remaining teeth [4].

Research has shown that changes in the oral environment can trigger adaptive responses in the brain's cortical areas. For example, tooth extraction in rats has been linked to neuroplastic changes in the primary motor cortex that controls facial movements. In humans, different types of dentures, such as implant-supported fixed dentures, implant-supported overdentures, and complete dentures, have been associated with varying patterns of neuronal activity related to chewing and clenching. Additionally, variations in the length of the dental arch of dentures can lead to distinct brain activity patterns in the middle frontal gyrus. The insertion of new dentures has also been found to alter activation in the precentral and postcentral gyri. These observations suggest that the brain's cortical areas may adapt to new dental appliances during the adjustment period [5].

Therefore, this review wants to shed light on current literature on neuroplastic effects on brain after different prosthodontic treatments.

Review of literature

Brain networks establish human behaviours

Research has shown that our expressive behaviours emerge from intricate, multilevel recurrent networks in the brain. At the lower levels of these networks, information is represented with high precision in terms of location, features, and timing. As you move to higher levels, these detailed representations are integrated into more complex forms, leading to an understanding of more sophisticated objects, relationships, and actions as they apply in the real world.

Cognitive therapists and rehabilitation specialists often concentrate on directly addressing clear, noticeable deficits in behavior. For example, if a person has memory problems, therapists usually work with them to practice memory exercises or develop strategies to cope with their memory loss. This method focuses on the immediate issues but might

overlook deeper, less obvious cognitive processes. A newer approach in neuroplasticity-based rehabilitation aims to target these underlying cognitive functions by utilizing the brain's capacity to reorganize and adapt, which could lead to more holistic improvements in both overt and subtle cognitive abilities. [6]

Masticatory neural control

Mastication is the initial phase of digestion and involves a rhythmic, intermittent action where the tongue, facial muscles, and jaw work together to position food between the teeth. This process cuts the food into smaller pieces and prepares it for swallowing.

Critical researches regarding the characteristics of a 'central pattern generator' located in the brainstem indicate that basic reflex circuits, like those controlling jaw opening and closing, cannot solely drive the rhythmic process of mastication. Rather, these reflexes play a role in fine-tuning chewing movements to ensure they are effective and to prevent potential damage to tissues [7-8].

The sensorimotor cortex, particularly the primary motor cortex and primary somatosensory cortex, along with other related regions, is vital for starting and precisely controlling mastication. This has been confirmed by multiple brain imaging studies in humans, which consistently reveal activation of cortical networks related to mastication, including the supplementary motor area (SMA), prefrontal cortex, and thalamus.

Implications for cortical neuroplasticity and rehabilitation of oral sensorimotor disorders and orofacial pain

Recent studies have investigated the brain's responses to mastication or jaw clenching in relation to different prosthodontic treatment through brain imaging. The findings have suggested that these responses vary depending on the success of the treatment. The tissue responses, occlusal characteristics, biomechanics, and the advantages of prosthodontic treatments like implants, bridges, and dentures have been examined and recent research has started to focus on the neural changes that occur when the stomatognathic system is disrupted, such as through tooth loss or intraoral pain. There has been growing interest in understanding the neural mechanisms behind these rehabilitative procedures, including why some patients quickly adapt and regain normal function while others struggle, and how these treatments achieve their therapeutic effects.

Furthermore, it was worth noting that pain can have great impact mastication. Studies in animals and humans found that pain generally reduces agonist muscle activity, increases antagonist muscle activity, and results in smaller jaw movements [9-10]. These results support Lund's pain-adaptation model [7]. However, additional research suggests that the adaptation of jaw motor function may be more intricate and influenced by individual differences, such as pain worsening, which might affect the specific regulation of jaw movements.

Adaptation to Complete/Partial Dentures

The effectiveness of prosthodontic treatment largely hinges on how well patients adjust to an altered oral environment with removable prostheses. Many patients find it uncomfortable to have their palate covered by removable dentures and struggle to adapt, even though maxillary dentures often cover the palate to ensure good retention and stability. Behavioural studies have shown that palatal coverage can negatively affect masticatory performance and bolus formation, with adjustments typically taking about a week.

Inamochi *et al*. supported the above statement by recording adaptive changes in chewing related brain activity through functional magnetic resonance imaging (FMRI). Following the insertion of the palatal plate in dentulous patients, there was an initial decrease in brain activation in the primary sensorimotor cortex, putamen, anterior cingulate cortex (ACG), and prefrontal cortex (PMFC). By seven days after the insertion, activation in the primary sensorimotor cortex and putamen began to show a tendency to rise due to acquisition of a new tongue movement pattern which might have altered brain activity in the primary sensorimotor cortex, leading to enhancements in food mixing ability and chewing functions [5].

These results suggest that adapting to palatal coverage during chewing is a key factor in getting used to removable dentures. Another study on replacement complete dentures' chewing efficiency and bite force, evaluated cortical changes during a period of 3 months and reported immediate changes in brain activity with the new dentures. [11] Wearing high-quality dentures, especially new ones compared to older models, can enhance the function of the masseter muscle and improve chewing efficiency. This improvement in chewing could positively influence attention and memory functions as well [4].

Kamiya *et al* analysed brain activity in elderly partially dentate subjects and young healthy controls using functional near-infrared spectroscopy (FNIRS). They evaluated prefrontal cortex functionality during chewing under conditions of denture use and tooth loss. There was marked prefrontal activity during chewing with a denture, accompanied by higher masticatory muscle activity, greater occlusal force, and improved masticatory scores, compared to when teeth were missing. The level of prefrontal activation during chewing with a denture in elderly individuals was comparable to that of young controls [12].

Functional neuroplasticity to implant based prosthetic rehabilitation

Tooth loss leads to neuroplastic changes in the motor representations of the jaw and tongue in the face-primary motor cortex and adjacent face-somatosensory regions. Since the discovery of 'Osseointegration' by P. I. Branemark, implant dentistry has flourished and led to successful rehabilitation of Partially or fully edentulous patients.

Wearers of complete dentures frequently report functional issues caused by inadequate retention and stability of the mandibular denture. The maximum bite force in denture wearers was reported to be only 20–40% of that seen in individuals with a full set of natural teeth. This reduced bite force was seen to be insufficient for breaking down certain natural foods, such as boiled meat, raw carrots, and rye bread [13].

Mandibular implant overdenture treatment is seen to be an effective solution for above individuals. The maximum bite force of implant supported overdentures was 60–200% higher than that of patients with a routine complete denture. These patients needed half the number of chewing cycles [14]. Also, the number of implants used for mandibular overdenture support and the choice between fixed or removable prostheses did not significantly impact masticatory performance. Similarly, the type of attachment

used, such as bar-clip, ball-socket, or magnet, had minimal effect on chewing function for patients with two mandibular implants [15-16].

Clinical outcomes for implant-supported single crowns (ISSCs) showed a notable increase in the number of near occlusal tooth contacts, the contact area, and the maximum bite force. Additionally, the center of occlusal load shifted significantly toward the posterior. The occlusal load on the posterior restorations was greater compared to the anterior ones, but the load on the ISSCs was lower, ranging from about 40–60% of the load experienced by the corresponding natural teeth.

Yeung *et al*., reviewed various studies and examined prosthetic rehabilitation options: complete dentures, implant-supported overdentures and implant-supported fixed dentures. Jaw-clenching studies indicated that implant-supported fixed dentures were the most favourable option compared to implant-supported overdentures and complete dentures whereas, gum-chewing studies revealed that complete dentures resulted in higher brain activity compared to implant-supported overdentures. It was suggested that complete dentures, being more mobile, caused a "more kinematically irregular and unstable chewing pattern" than implant-supported overdentures, leading to increased brain activation. It also shed light upon medial and middle frontal gyri- which are linked to masticatory functions, including food comminution and mixing. These functions appeared to improve when the entire dental arch was fully replaced rather than partially replaced. In conjunction, patients showed significantly higher brain activation in the hippocampus and prefrontal cortex after wearing implant-supported overdentures for three months, compared to those who wore complete dentures for the same period [4].

Effect of occlusal splint therapy

Performing various occlusal functionality tasks results in different patterns of brain activation. It has been suggested that occlusal splints may decrease brain activity and relax muscle tension. Variations between the left and right brain hemispheres have been associated with differences in chewing laterality, and the functionality of the sensorimotor cortex is related to chewing processes [17-18].

Other researches have shown that using a rigid splint to increase the vertical dimension activates brain regions involved in reasoning, movement coordination, and memory. This leads to more extensive brain activity and a notable decrease in muscle activity during clenching. Furthermore, Occlusal splint therapy helps reduce mental strain and anticipatory pain related to anxiety by decreasing activation in the insula. Additionally, splints adjust the spacing between the condyle and the temporomandibular joint fossa, improving the symmetry of jaw movements [19].

Conclusion

The current review highlights that the mechanisms governing and controlling mastication are numerous and intricate. Recent studies have shown that neuroplasticity, arising from changes in the orofacial system, may be linked to the adaptation to prostheses. fMRI research studies indicate that some rehabilitation approaches are more effective in restoring masticatory functions and associated brain activity levels.

Recent innovations in Virtual, Augmented, and Mixed Realities within dental and prosthodontic fields, including holographic displays of internal dental conditions and interactive simulators, have opened new possibilities for examining digital dental models. These technologies aid in evaluating cortical responses and enhance the oversight of prosthodontic procedures.

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