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## TRANSCRANIAL DIRECT CURRENT STIMULATION AS A TREATMENT FOR DEPRESSION: EFFICACY AND SAFETY

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**Abstract:** Transcranial direct current stimulation (tDCS) stands out as an innovative and affordable therapeutic alternative for the treatment of major depressive disorder (MDD). This study reviewed 29 articles published between 2020 and 2024 in the PubMed database, showing the benefits of tDCS in relieving depressive symptoms, reducing suicidal ideation and improving sleep quality. The technique demonstrated safety and feasibility, even in home settings, and increased efficacy when combined with psychotherapies or antidepressants. Despite advances, challenges remain, such as standardizing protocols, identifying ideal parameters and validating long-term effects. The variability of the results highlights the need for additional studies that integrate technologies such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG), allowing for greater precision in the stimulation of target regions. We conclude that tDCS represents a promising innovation in psychiatry, with the potential to redefine clinical practices and democratize access to effective treatments. Investments in longitudinal research and integration with advanced technologies are crucial to maximize its benefits and consolidate its application in broad and diverse populations.

**Keywords:** transcranial stimulation, major depressive disorder, neuromodulation, psychiatry.

## INTRODUCTION

Transcranial direct current stimulation (tDCS) has been highlighted as an emerging therapeutic approach in the field of psychiatry, especially in the treatment of major depressive disorder (MDD). For Gupta and Mittal (2021), tDCS offers a promising approach to managing emotional processing deficits in patients with depression, with advantages such as affordability and safety. This technique, which modulates dysregulated neural circuits through low-intensity electrical currents, has

shown potential in reducing depressive symptoms and improving the quality of life of patients with different degrees of severity of the disorder (Woodham *et al.*, 2021).

The relevance of tDCS in psychiatry is also associated with its ability to promote neuroplasticity and alter functional connectivity in critical brain regions, such as the prefrontal cortex. For Benster *et al.* (2023), tDCS is an emerging and effective approach to modulate dysregulated neural circuits in psychiatric disorders, while Buchanan, Robaey and D'Angiuli (2020) point out that its accessibility and safety contribute to its clinical acceptance. Despite its potential, there are controversies regarding the optimization of stimulation parameters and efficiency in cases of treatment-resistant depression (Cho *et al.*, 2022).

Although the current literature shows the positive impact of tDCS in relieving depressive symptoms, significant gaps remain, as pointed out by Albizu *et al.* (2024). These authors point out that the personalization of stimulation based on individual anatomical characteristics represents an important advance in reducing the variability of results and improving therapeutic efficacy. According to Chase *et al.* (2020), tDCS has the potential to positively influence cognition and behavior, but there is a need for studies to clarify its mechanisms of action and determine the best application protocols (Murphy *et al.*, 2023).

The need for more in-depth studies is also reinforced by Wang *et al.* (2021), who point out the importance of therapeutic combinations, such as the use of tDCS together with antidepressant drugs, to increase the response rate and remission. For Woodham *et al.* (2021), its efficacy is greater in cases of non-resistant depression, but the heterogeneity of the results highlights the urgency of standardizing protocols and investigations that integrate complementary technologies, such as Functional Magnetic Resonance Imaging (fMRI) and electroencephalography (EEG) (Albizu *et al.*, 2024).

This study aims to analyze the efficacy and safety of tDCS as a therapeutic modality for the treatment of depressive symptoms, comparing it with traditional treatments and exploring its impact in the short and long term. This research aims to fill gaps in the literature and contribute to the consolidation of tDCS as a safe and effective intervention in the field of psychiatry.

## METHODOLOGY

This is a literature review developed according to the criteria of the PVO strategy, which stands for: population or research problem, variables and outcome. This strategy was used to develop the research question “What is the efficacy and safety of transcranial direct current stimulation (tDCS) as an intervention in the treatment of patients with depression?”. The searches were carried out using the PubMed - MEDLINE (Medical Literature Analysis and Retrieval System Online) databases. The search terms were used in combination with the Boolean term “AND”, using the following search strategy: (transcranial direct current stimulation) AND (depression) AND (treatment). From this search, 470 articles were found, which were then submitted to the selection criteria. The inclusion criteria were: articles in English; published between 2020 and 2024 and which addressed the themes proposed for this research, review and meta-analysis type studies, available in full. The exclusion criteria were: duplicate articles, available in abstract form, which did not directly address the proposal studied and which did not meet the other inclusion criteria. After applying the search strategy to the database, a total of 61 articles were found. After applying the inclusion and exclusion criteria, 29 articles were selected from the PubMed database to make up this study's collection.

## DISCUSSION

A detailed analysis of the literature on transcranial direct current stimulation (tDCS) in the treatment of major depressive disorder (MDD) reveals a consistent and promising body of evidence. According to Fregni *et al.* (2021), tDCS has been classified as definitively effective for the treatment of depression, which reinforces its clinical application in different settings. Additional studies, such as that by Chen *et al.* (2024), show a significant reduction in suicidal ideation after the use of prolonged protocols, which demonstrates the versatility of the technique in therapeutic approaches. Furthermore, in home settings, Woodham *et al.* (2022) report high remission rates, which highlights the feasibility and safety of this approach in remote care.

Other studies, such as that by Wang *et al.* (2022), highlighted the effectiveness of transcranial alternating current stimulation (tACS) in attenuating depressive symptoms, while Zhou *et al.* (2020) explored the positive effects of tACS in improving sleep quality and reducing insomnia symptoms associated with depression. These findings were corroborated by Razza *et al.* (2021), who emphasized the role of tDCS and high-frequency transcranial magnetic stimulation (HF-rTMS) as effective neuromodulation techniques, highlighting the contribution of these interventions in the management of major depression.

In addition, Ramasubramanian *et al.* (2022) provided an important comparison between tDCS and electroconvulsive therapy (ECT) in the treatment of resistant depression. Although ECT proved to be more effective in severe cases, tDCS stood out for its safety and acceptance by patients, with less invasive side effects. These findings reinforce the complementary role of tDCS in clinical situations where ECT may not be viable.

Singh *et al.* (2020) contributed to the critical analysis by exploring the differences between tDCS and rTMS. The less focal and more comprehensive tDCS was touted as an affordable and effective approach, especially when customized based on functional neuroimaging.

The results reviewed point to a general consensus on the safety and efficacy of tDCS, but also highlight discrepancies that deserve attention. For example, Chen *et al.* (2023) observed a more significant impact on anxiety symptoms when using 60-minute protocols, while Burkhardt *et al.* (2023) found no substantial differences between active and sham tDCS as a complement to selective serotonin reuptake inhibitors (SSRIs). These discrepancies possibly reflect variations in protocol parameters, including intensity, session duration and electrode location.

An interesting contrast is provided by D'Urso *et al.* (2022), who integrated bilateral frontal and cerebellar stimulation into their protocols, which resulted in substantial improvements in depression scores. On the other hand, Nobakhsh *et al.* (2023) highlighted the potential of EEG-based biomarkers for personalizing treatments, suggesting that technological advances could optimize both tDCS and other neuromodulation techniques. These findings indicate the need for a more refined approach to ensure consistency in results. Studies such as those by Boscutti *et al.* (2023) have highlighted the potential of integrating biomarkers and brain connectivity analysis to optimize neuromodulation protocols. These theoretical advances could refine the clinical application of tDCS, especially in populations with complex symptoms. In addition, Baliga *et al.* (2020) reported the success of tDCS in cases of bipolar depression, reinforcing its viability in a variety of affective disorders. The combination of tDCS with mood stabilizers has been shown to prevent adverse affective changes, demonstrating its safety in challenging contexts.

Ruffini *et al.* (2024) significantly expanded the theoretical understanding of the use of multichannel tDCS protocols, optimizing stimulation in target regions such as the left dorsolateral prefrontal cortex (DLPFC). These contributions reinforce the central role of neuroplasticity in relieving depressive symptoms, highlighting the relationship between cortical networks and emotional regulation. The possibility of using ETCC at home, as reported by Woodham *et al.* (2022) and Ruffini *et al.* (2024), represents a significant milestone in democratizing access to treatment, especially for patients with mobility limitations or geographical barriers. Additionally, Huang *et al.* (2021) highlighted the cognitive benefits of tACS, suggesting that such interventions may have practical applications that transcend the management of depressive symptoms, including improving attention and executive control.

Despite the significant advances described, studies such as that by Guo *et al.* (2024) reinforce the need for investigations in larger and more diverse populations in order to validate preliminary findings. In addition, Fregni, El-Hagrassy and Barrios (2021) pointed to a clear gap in the standardization of protocols, which limits the generalization of results and makes direct comparison between studies difficult.

Future research should focus on the integration of technologies such as fMRI to identify specific stimulation targets (Chen *et al.*, 2022) and explore therapeutic combinations, such as the association of tDCS with psychotherapies or interventions based on cognitive-emotional training (Nikolin *et al.*, 2020).

## FINAL CONSIDERATIONS

Transcranial direct current stimulation (tDCS) has emerged as a promising and affordable therapeutic alternative in the treatment of major depressive disorder (MDD), offering benefits such as safety, feasibility in home environments and the potential for personalization based on biomarkers and advanced technologies. The studies reviewed demonstrated efficacy in relieving depressive symptoms, improvements in sleep quality and a reduction in suicidal ideation, as well as promoting neuroplasticity and benefits in cognition, especially when combined with other treatments such as psychotherapies or antidepressants. These findings highlight the growing role of tDCS in psychiatry, expanding the possibilities of clinical management for cases of resistant depression and other affective disorders. However, challenges remain, including standardizing protocols, identifying optimal stimulation parameters and exploring its long-term effects. The variability in results, related to factors such as intensity, electrode location and session duration, reinforces the need for further studies to refine therapeutic guidelines. In addition, ethical and economic issues must be considered, especially in regions with limited access to neuromodulation technologies. Future research should focus on integrating tDCS with tools such as fMRI and EEG, promoting greater precision in the stimulation of target regions and optimizing results. The expansion of longitudinal and multicenter studies will be crucial to consolidate its efficacy in broader and more diverse populations. The association of tDCS with combined interventions also presents a promising field, with the potential to maximize the therapeutic response and ensure greater sustainability of the effects obtained.



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