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# Neuromodulation as a novel approach for postoperative endodontic pain management: A focus on tDCS

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**Abstract**
Postoperative endodontic pain remains a frequent challenge and a major determinant of patient satisfaction. Its multifactorial etiology involves microbial persistence, periapical inflammation, and central and peripheral sensitization. Conventional pain management strategies include pharmacological measures such as analgesics, anti-inflammatory drugs, and intracanal medicaments, along with non-pharmacological approaches like cryotherapy, low-level laser therapy, and occlusal reduction. In addition, endodontic techniques such as rotary crown-down instrumentation have demonstrated value in minimizing apical debris extrusion and reducing postoperative discomfort.
Although these modalities may alleviate symptoms, none are universally effective. Inadequate pain control can disrupt patients' daily lives, interfere with sleep, eating, and work performance, and contribute to heightened dental anxiety, thereby affecting treatment compliance and overall quality of life. Neuromodulation techniques, particularly transcranial direct current stimulation (tDCS), have shown promising results in chronic pain conditions by modulating cortical excitability and altering pain perception networks. These findings suggest that tDCS could be adapted into dental practice to not only reduce pain but also improve patients' psychological well-being, functional recovery, and confidence in dental care.

**Keywords:** Postoperative endodontic pain, Neuromodulation, Transcranial direct current stimulation (tDCS), Pain management

## Introduction
Postoperative endodontic pain is a frequent outcome of root canal therapy and can significantly impact patient experience and treatment acceptance [1]. Its origins are multifactorial, involving microbial factors, periapical tissue response, and central pain mechanisms [2]. Despite the availability of analgesics, anti-inflammatory agents, intracanal medicaments, and supportive approaches such as cryotherapy and laser therapy, consistent pain control remains a challenge [3].
Emerging evidence suggests that neuromodulation techniques, particularly transcranial direct current stimulation (tDCS), may provide additional benefits by targeting central mechanisms of pain perception [4].
This review outlines current approaches to postoperative endodontic pain management and evaluates the potential role of tDCS as a novel adjunctive strategy.

## Review
### Significance of Pain in Endodontics
Pain control is central to the practice of dentistry, as the general population often associates dental treatment with pain and considers them almost synonymous. For patients, the relief of pain is usually the highest priority, making its management a primary concern for the endodontist [5].
Accurate diagnosis is equally essential, since clinicians must distinguish between odontogenic

and non-odontogenic sources of pain. Most patients present with severe discomfort of endodontic or periodontal origin, with endodontic causes being the most common. Therefore, precise identification of the source of pain—through careful clinical examination, pulp and periapical testing, and the use of two- and three-dimensional radiographic imaging—forms the foundation of effective endodontic pain management [3]

**Biological Basis of Dental Pain**

Dental pain is a subjective experience that integrates sensory, emotional, and motivational components [5]. It is recognized as the most frequent cause of orofacial pain [6], with pulpal and periapical conditions being the leading reasons patients seek dental care [7].

The phenomenon of dental pain is complex, involving multiple mechanisms and pathways. Understanding these mechanisms is crucial for developing more effective strategies for pain management. Pain arises through a series of processes beginning with the detection of noxious stimuli and ending with the transmission of these signals to the central nervous system [3].

Typically, dental pain originates from stimulation of nerves within the tooth and its surrounding tissues. This may occur due to caries, trauma, periodontal disease, or dental procedures. Nerve fibers within the dentinal tubules and pulp can be activated by thermal, mechanical, or chemical stimuli, triggering nociceptors and initiating pain signals. This process, known as peripheral sensitization, plays a central role in the pathogenesis of dental pain [11].

**Nerve Fibers Involved in Dental Pain**

The trigeminal nerve is the principal pathway for transmitting dental pain. It divides into maxillary, mandibular, and ophthalmic branches, which supply the teeth, jaws, and face. Within the dental pulp and periapical tissues, specialized nerve fibers act as nociceptors. Among them, A-delta fibers and C fibers are the primary mediators of dental pain [12-13].

A-delta fibers are thinly myelinated fibers responsible for sharp, well-localized, and short-lasting pain. They are typically activated by thermal, mechanical, or osmotic stimuli such as cold air, sweet foods, or drilling. Their main clinical characteristic is sensitivity to hydrodynamic stimuli, which cause rapid fluid movement within dentinal tubules. This movement stimulates mechanosensitive nerve endings, producing the characteristic short, sharp pain [12-13, 14-17]. Clinical scenarios such as cavity preparation, dentin desiccation, or exposure of root dentin through scaling or abrasion often provoke A-delta fiber activity.

In contrast, C fibers are unmyelinated, smaller in diameter, and slower conducting. They have higher excitation thresholds and are activated primarily by heat or by persistent noxious stimuli associated with pulpal inflammation. Pain mediated by C fibers is typically dull, diffuse, throbbing, and long-lasting, often signaling more advanced or irreversible pulpal damage [9-10, 12]. Because these fibers are located deeper within the pulp, they are less affected by mild external stimuli but dominate in chronic or severe conditions. Furthermore, unlike A-delta fibers, C fibers can survive longer under hypoxic conditions, as they consume less oxygen. This ability explains why dull, lingering pain persists in inflamed or ischemic pulps, while A-delta activity diminishes [19].

**Pulpal Inflammation and Pain Mechanisms**

Two main elements contribute to pulpal inflammation: nerve fiber activation and microcirculatory changes. When pulpitis occurs, pain is particularly severe due to the unique anatomical constraints of the pulp chamber. The dental pulp is enclosed within rigid dentin and enamel, leaving little capacity for expansion. In most tissues, inflammation produces swelling as immune cells and fluid accumulate; however, in the pulp this swelling cannot expand outward. Instead, the confined environment results in a rise in intrapulpal pressure [8].

The pulp is highly vascularized and innervated, and when intrapulpal pressure increases, nociceptive fibers (A-delta and C fibers) become compressed, producing intense pain. Further pressure can restrict blood flow, leading to ischemia, pulp necrosis, and the characteristic throbbing pain seen in irreversible pulpitis [10].

In addition, proinflammatory mediators such as prostaglandins, bradykinin, and histamine are released during pulpal inflammation. These substances lower the excitability threshold of nociceptors, causing even minor stimuli—such as mild pressure or temperature changes—to trigger intense pain [9]. This process of peripheral sensitization explains the heightened reactivity of inflamed pulp tissue.

At the cellular level, mediator-receptor interactions activate secondary messenger pathways, protein kinases, and phospholipases, which in turn stimulate ion channels. Their opening allows ion passage, depolarization, and propagation of nociceptive action potentials. Neuropeptides such as substance P contribute to neurogenic inflammation, amplifying vascular and immune responses and further sensitizing the pulp [9-10].

Activated nociceptors transmit pain impulses through the trigeminal nerve to the trigeminal ganglion, then to the brainstem and thalamus, and ultimately to the cerebral cortex, where pain is consciously perceived [10].

**Post-Operative Endodontic Pain**

In endodontic therapy, all pre-, intra-, and post-operative symptoms are managed, including post-operative endodontic discomfort, which is regarded as a problem that can become chronic.

With a multifactorial etiology and a possible pathogenic relationship to acute periapical inflammation brought on by localized chemical, mechanical, host, and/or microbial damage during endodontic treatment, post-operative discomfort is extremely prevalent and highly unpreventable. [3, 18] Post- operative endodontic pain refers to discomfort or pain experienced after undergoing an endodontic treatment such as root canal procedure. While endodontic treatments aim to relieve the pain caused by inflammation and infection in the pulp, it's common to experience some level of pain or discomfort following the procedure. This pain usually subsides within a few days, but in some cases, it can persist or worsen due to various factors. [3]

Effective control and management of post-operative endodontic pain are indispensable aspects of care. Proper patient education regarding expected pain responses, along with appropriate pharmacological interventions not only reduce discomfort but also strengthen patients' trust in their dentist, improves pain tolerance, and positively shapes their perception of future dental treatments [20-21].

**Incidence and Characteristics of Post-Operative Endodontic Pain**

According to the literature, pulp therapy and root canal treatment are more likely to elicit post-
operative pain compared to other dental procedures [22-23]. The

reported prevalence of post-operative endodontic pain ranges widely from 2.5% to nearly 60% of treated cases [2]. This wide variation is largely due to differences in how studies defined and assessed post-operative pain. Many investigations focused only on severe cases associated with swelling or those requiring emergency visits, while patients experiencing mild or tolerable discomfort were often excluded [24].

The onset of post-operative pain typically peaks between 6 and 12 hours after treatment, affecting up to 40% of patients within the first 24 hours, and then gradually decreases to around 11% within one week [25-27]. Despite advances in endodontic techniques, post-operative discomfort remains difficult to fully prevent, as it is influenced by a variety of factors. These include patient-related variables (such as age, gender, and pain perception), tooth-related characteristics (such as pre-operative pulp status and tooth type), and treatment-related aspects (such as whether it is a primary root canal therapy or retreatment) [27].

Mild to moderate post-operative pain is generally considered a normal part of the healing process. Its occurrence may result from multiple factors, including the initial condition of the pulp, the mechanical and biological interventions performed, and the patient's individual physiological response [29-31].

Given its multifactorial nature and high prevalence, understanding and implementing effective strategies for the management and control of post-operative endodontic pain are essential for improving patient comfort and treatment outcomes.

**Etiological Factors of Post-Operative Endodontic Pain**

Post-operative endodontic pain can result from a variety of procedural and biological factors during or after root canal therapy.

**Instrumental and Procedural Trauma**

Over-instrumentation may traumatize the periapical tissues, causing localized inflammation, soreness, and pain. Conversely, under-instrumentation can lead to persistent infection and discomfort due to incomplete cleaning and shaping, leaving necrotic tissues and microorganisms within the canal system. Similarly, overextension of root canal filling material beyond the apex may irritate and inflame surrounding tissues [32].

**Irrigation and Intracanal Medication Trauma**

Irrigation trauma may occur when irrigants inadvertently extrude beyond the root apex, irritating periapical tissues and causing temporary pain or inflammation [33-34]. In addition, intracanal medications such as calcium hydroxide, if extruded excessively beyond the apical foramen, can provoke an inflammatory response leading to post-operative pain [28].

**Structural and Anatomical Factors**

Undiagnosed cracks or fractures in a treated tooth may result in persistent post-operative pain and, in some cases, necessitate extraction [35]. Complex root canal anatomy or inaccessible accessory canals increase the risk of bacterial persistence, reinfection, and subsequent periapical inflammation, which may prolong symptoms [38]. Extrusion of necrotic debris or microorganisms during canal instrumentation, especially when checking apical patency, may further exacerbate periapical irritation and pain [38-39].

**Material-Related and Host Response Factors**

Root canal filling material that is overextended or underfilled can either irritate surrounding periapical tissues or allow residual infection to persist, both of which may contribute to post-operative discomfort [36-36]. Although uncommon, some patients may experience hypersensitivity or allergic reactions to endodontic materials or medicaments, leading to pain and inflammation [39].

**Occlusal Trauma**

Occlusal discrepancies, such as a high final restoration, may cause excessive occlusal forces on the treated tooth during mastication. This mechanical overload, combined with an already inflamed periapical region, can result in prolonged pain and mechanical allodynia [40-41]. In patients presenting with severe pre-operative pain, it may be advisable to relieve the treated tooth from occlusion temporarily to minimize post-operative discomfort [42-43].

Overall, post-operative endodontic pain is multifactorial, often arising from a combination of procedural, anatomical, and biological factors. Recognizing these etiological contributors is essential for clinicians, as it provides the foundation for effective strategies to prevent, minimize, and manage post-treatment discomfort.

**Clinical and Demographic Risk Factors of Post-Operative Endodontic Pain**

In 2014, a cross-sectional study investigated the association between post-operative pain after endodontic therapy and several clinical factors, including age, gender, tooth type, pulpal diagnosis, preoperative pain, obturation length, and sealer extrusion. The study concluded that female gender, mandibular molars, and the presence of preoperative symptoms were significant risk factors associated with post-operative pain, with the strongest association found between preoperative pain and post-treatment discomfort [44].

**Gender**

Several studies have consistently reported higher pain levels in females compared to males [45].

This may be explained by a generally lower pain threshold observed in females [46]. Polycarpou also identified female gender as a critical risk factor strongly associated with persistent pain following endodontic therapy [50].

**Tooth Type**

The relationship between tooth type and post-operative pain has been less conclusive. Some studies found no significant association, reporting similar outcomes across different tooth types [47-49]. However, other investigations, including Harrison's work, indicated that mandibular molars were more frequently associated with moderate post-operative pain than maxillary molars, a finding also supported by additional studies [49-51].

**Pulpal and Preoperative Status**

The pulpal diagnosis prior to treatment appears to play an important role. Teeth diagnosed with acute pulpitis were more likely to present with moderate to severe post-operative pain compared to teeth with chronic pulpitis, pulp necrosis, or apical periodontitis [52]. Similarly, Abdel Hameed reported that patients with preoperative symptoms experienced a significantly higher incidence of post-operative pain compared to asymptomatic cases [53]. Other studies have also confirmed the strong link between preoperative pain and subsequent post-treatment discomfort [49, 55-56].

**Sealer Extrusion**

Interestingly, the extrusion of root canal sealer did not demonstrate a statistically significant association with post-operative pain in most studies [54].

Collectively, the evidence suggests that gender, preoperative symptomatology, and—less consistently mandibular molars are key risk factors for post-operative pain, while factors such as sealer extrusion appears to play a minimal role. These insights are critical for identifying high-risk patients and tailoring pain management strategies accordingly.

**Pain Management in Endodontics**

Pain management techniques have advanced significantly over time. Controlling endodontic pain at all stages—preoperative, perioperative, and postoperative—can be achieved through diverse, evidence-based approaches. Pain control should be initiated before treatment begins, maintained during dental care, and continued postoperatively until signs and symptoms of inflammation and infection subside [58].

**Non-pharmacological approach**

Non-pharmacological strategies remain the first step. These include psychological preparation of the patient by clearly explaining treatment steps, reassuring that procedures are painless, and informing them about possible mild discomfort afterward. Such patient education reduces dental anxiety, elevates the pain threshold, and enhances anesthetic success. Dental anxiety is known to produce genomic changes in nociceptors, leading to peripheral sensitization, lower pain thresholds, and delayed healing [57].

**Pharmacological approach**

**Medications**

Over the past decade, pharmacological interventions have evolved to improve pain control.

Pretreatment with non-narcotic analgesics such as NSAIDs (e.g., ibuprofen 800 mg, flurbiprofen 100 mg) has proven effective in reducing postoperative pain. For patients contraindicated to NSAIDs such as those with gastrointestinal disorders, peptic ulcers, asthma, or hypertension acetaminophen (1000 mg) is a safe and effective alternative [59-63].

NSAIDs work by inhibiting COX-1 and COX-2 enzymes, thereby reducing prostaglandin synthesis, which mediates both pain and inflammation [64]. The recommended maximum daily dose of ibuprofen is 3200 mg, commonly administered as 400-800 mg every 4-8 hours [65].

However, gastrointestinal upset is a dose-dependent side effect; hence, the lowest effective dose should be used [66-68].

Acetaminophen, in contrast, acts peripherally by inhibiting prostaglandin synthesis [69] and centrally by interacting with cannabinoid and serotonergic receptors, reinforcing descending pain pathways [70]. The maximum recommended daily dose is 3000 mg [71], and exceeding this may risk hepatotoxicity [72].

Pretreatment with NSAIDs in cases of irreversible pulpitis lowers pulpal prostaglandin E2 levels, which not only minimizes nociceptor sensitization (improving anesthetic success) but also reduces activation of TTX-resistant sodium channels that contribute to anesthetic resistance [73-74].

Corticosteroids (e.g., prednisolone, dexamethasone) and opioids (e.g., tramadol) have also demonstrated efficacy in severe pain control [75]. Corticosteroids suppress inflammation by inhibiting phospholipase activity, thereby reducing the release of arachidonic acid and downstream mediators such as prostaglandins and leukotrienes [76]. However, due to their immunosuppressive risks, corticosteroids are considered adjunctive treatments and should only be used when other anti-inflammatory drugs are ineffective eg. flare-ups without infection, acute inflammation). [77-78].

Opioids, while capable of reducing anxiety and producing analgesia via mu and kappa receptor activity [79], carry significant risks of dependence and addiction. Therefore, they are not recommended as first-line agents and should only be prescribed in severe cases.

A clinical study by Maryam Zanjir demonstrated that patients taking NSAIDs, acetaminophen, or other medications experienced a greater reduction in postoperative pain at 6, 12, and 24 hours compared with placebo. However, by 48 hours, pain reduction was similar across all groups (86%), highlighting the importance of pain control within the first 24 hours after treatment [80].

Similarly, Park and White reported a 90% decrease in postoperative pain within 7 days of endodontic therapy [81].

Interestingly, the combination of NSAIDs with acetaminophen provided significantly greater pain relief in the first 6-8 hours than NSAIDs alone, though differences became insignificant after 12-24 hours. This suggests that the synergistic effect is most beneficial in the immediate postoperative period, after which NSAIDs alone are sufficient. Conversely, combining NSAIDs with opioids showed no additional benefit. The American Dental Association (ADA) has emphasized that opioids should never be prescribed as first-line therapy but only for severe, uncontrolled pain. Corticosteroids and antibiotics have also been shown to have no significant role in reducing postoperative endodontic pain [80].

**Anesthesia**

Profound local anesthesia remains the cornerstone of perioperative pain management. However, patients with severe endodontic pain, particularly those with symptomatic irreversible pulpitis, often fail to achieve complete anesthesia [82]. This failure may be related to the technique used, altered tissue pH, or inflammatory changes that impair anesthetic efficacy [83]. Pain-free treatment is critical, as negative dental experiences can discourage patients from seeking future dental care [84].

For maxillary teeth, buccal infiltrations alone are typically sufficient, with posterior superior alveolar nerve blocks or palatal anesthesia offering no additional benefit [85]. In contrast, achieving pulpal anesthesia in mandibular teeth is more challenging. While infiltrations may be effective for mandibular anteriors, premolars respond best to a combination of mental and inferior alveolar nerve block (IANB) injections [86-87]. Mandibular molars generally require block anesthesia, often supplemented with adjunctive techniques, as IANB alone has relatively low success rates. Alternative block approaches, such as the Gow-Gates and Vazirani-Akinosi techniques, have not demonstrated superior outcomes [87-88].

Among adjuncts, buccal infiltration with articaine provides the highest efficacy when combined with IANB. Other useful methods include intraligamentary and intraosseous anesthesia [89].

When all techniques fail, or when breakthrough pain arises during treatment, intrapulpal anesthesia remains a reliable last resort [90].

The choice of anesthetic solution itself does not appear to significantly influence success. Both articaine and lidocaine are equally effective for infiltration anesthesia [91], while mepivacaine and lidocaine show no differences in block anesthesia efficacy [92]. Instead, anesthetic volume plays a more critical role: administration of 3.6 mL via IANB significantly reduces pulpal anesthesia failure in mandibular molars compared to 1.8 mL [93].

In some patients, local anesthesia alone may be inadequate for perioperative pain control. In such cases, adjunctive pharmacologic agents may be considered. Nitrous oxide enhances analgesia and improves anesthetic efficacy [94], while benzodiazepines do not potentiate anesthesia but can reduce procedure-related anxiety [95]. Preoperative use of oral agents including dexamethasone, NSAIDs, or tramadol—has been suggested to improve IANB effectiveness in symptomatic irreversible pulpitis, although evidence remains controversial [96].

**Apical Patency**

Apical patency may reduce early postoperative pain by improving drainage [97], but analgesic use often remains necessary. Evidence quality is low, and further high-quality trials are needed.

**Impact of Instrumentation Techniques on Post-Operative Pain**

A 2016 study compared post-operative pain following single-visit endodontic treatment using hand K-files versus Mtwo rotary instruments. The findings indicated that patients treated with Mtwo rotary instruments experienced significantly less post-operative pain compared to those treated with hand K-files [98].

**Postoperative Pain Management: Crown-Down vs Step-Down Techniques Using RaCe Rotary System**

A recent study compared postoperative pain after endodontic treatment of mandibular molars with asymptomatic irreversible pulpitis using the RaCe rotary system, evaluating the crown-down versus step-down techniques. The results demonstrated no significant difference between the two techniques in terms of postoperative pain, indicating that both methods provide effective pain management in such cases. This finding aligns with existing strategies that emphasize technique selection alongside pharmacological and non-pharmacological measures to optimize patient comfort after endodontic procedures. [99]

**Intracanal Medicaments**

Recent studies highlight the importance of intracanal medicaments in managing postoperative pain. Systematic reviews indicate that calcium hydroxide can significantly reduce pain at 24 hours post-treatment, particularly in patients with apical periodontitis [100]. Combination therapies using steroids, antibiotics, or chlorhexidine further enhance this effect, especially in symptomatic cases [101-104]. These findings reinforce the role of intracanal medicaments as an adjunct to comprehensive pain management strategies, complementing both local anesthesia and systemic pharmacological interventions.

**Diode Laser Therapy in Post-Endodontic Pain Control**

Recent advances in pain management following endodontic therapy have explored the application of diode laser therapy through two approaches: low-level laser therapy and laser-activated irrigation. These techniques were compared with mock laser therapy, and results demonstrated that low-level laser therapy provided superior pain reduction within the first 24 hours. After 48 hours, both laser techniques showed comparable outcomes, with each producing significantly greater pain relief than mock therapy [105].

**Cryotherapy in Reducing Post-Endodontic Pain**

Recent research has also explored the use of cryotherapy as an adjunct for postoperative pain reduction in endodontic therapy. In a study by Mohamed Shaker, intracanal irrigating solutions (saline and chlorhexidine) delivered through cryotherapy were tested, and results showed significant pain reduction regardless of the irrigant used [106].

Vera confirmed these findings in a similar study, where chilled saline at 2.5 °C was delivered for five minutes using the EndoVac system. The reduction in root surface temperature was attributed to the well-documented benefits of cold therapy in managing trauma and promoting recovery in surgical procedures [107].

Cryotherapy, therefore, can be considered an efficient, safe, and cost-effective method to reduce postoperative pain following single-visit endodontic treatment [108].

**Root Canal Sealers**

Most reviews show no significant difference in postoperative pain between resin-based and bioceramic sealers [109]. Some studies suggest bioceramic sealers may slightly reduce pain, especially at 24-48 hours, but evidence is inconsistent and biased [110].

**Occlusal Reduction**

Evidence on occlusal reduction for postoperative pain is mixed. Some studies report pain relief after 2-3 days, particularly in teeth with irreversible pulpitis or symptomatic apical periodontitis [111]. However, early pain relief within the first 24-48 hours is minimal, and the overall evidence is limited, warranting further high-quality research.

**Single-Visit versus Multiple-Visit Root Canal Treatment**

Systematic reviews show mixed findings regarding postoperative pain between single-visit and multiple-visit treatments. Some reviews report no significant difference, while one suggests a slightly higher pain incidence with single-visit treatments [112]. Limitations such as small sample sizes and high heterogeneity reduce the reliability of these conclusions, indicating the need for further high-quality trials.

**Post-Endodontic pain and the need for ongoing advances**

Postoperative pain following endodontic therapy typically peaks within the first two days and usually subsides within a few hours [113-114]. In some cases, however, discomfort may persist for several days [115-117]. A recent systematic review reported that approximately 40% of patients experience pain during the first 24 hours after root canal treatment, while about 11% continue to report pain even after seven days [115]. This highlights the ongoing challenge clinicians face in managing pain associated with root canal therapy [118].

Patient communication plays a vital role in this process. Dentists should inform patients that some degree of discomfort is common and provide clear verbal and written instructions distinguishing between expected postoperative pain and warning signs that necessitate contacting the clinician [119-120]. Pharmacologic management typically involves oral medications such as acetaminophen, ibuprofen,

or their combination, while the routine use of opioid-based drugs should be avoided whenever possible [121-122].

Despite the effectiveness of current techniques and medications, limitations remain. In acute pulpal or periapical conditions, as well as in cases of postoperative flare-ups, conventional pharmacologic interventions may fail to provide adequate pain relief. As a result, patients can still experience severe and intolerable pain before, during, or after endodontic treatment. This persistent challenge underscores the need for continued research and the development of novel technologies, techniques, and medications to improve pain management outcomes [123].

**Transcranial Direct Current Stimulation (tDCS) in Pain Management**

Based on its proven success in managing pain associated with non-therapeutic chronic diseases [124], transcranial direct current stimulation (tDCS) has been proposed as a novel approach for pain control in the dental field.

tDCS is a noninvasive, portable, and reversible brain stimulation technique that delivers a low, constant electrical current (0.5-2 mA) through electrodes placed on the scalp. By modulating neuronal activity in targeted brain regions, it can either enhance or inhibit neural function [125-126]. Many studies have demonstrated that activating areas such as the motor cortex (M1) and dorsolateral prefrontal cortex (dlPFC) with tDCS significantly reduces chronic pain. A systematic review analyzing more than 554 studies confirmed its growing application, particularly in chronic conditions like fibromyalgia and lower back pain, suggesting that electrode placement and pain type influence its analgesic effects [125].

The use of tDCS has expanded rapidly in recent years, enabling researchers to better understand the cortical substrates underlying pain perception and behavior. These advancements highlight its potential not only as a therapeutic tool but also as a means of uncovering how brain modulation can shape sensory and cognitive responses [124].

Given the persistent challenge of managing post-endodontic pain and the limitations of current pharmacological options, tDCS represents a promising innovative strategy that could be translated from chronic systemic pain management into endodontic clinical practice

**Clinical Trials of tDCS in Chronic Pain Disorders**

**Application of tDCS in Fibromyalgia**

In 2006, researchers hypothesized that transcranial direct current stimulation (tDCS) could help relieve pain in patients with fibromyalgia, a chronic condition linked to altered brain activity. A randomized clinical trial was conducted where one group received sham stimulation and the other active tDCS, with electrodes placed on either the dorsolateral prefrontal cortex or the primary motor cortex. Pain was measured using a visual analogue scale by a blinded assessor, and the findings revealed that patients receiving active tDCS reported a noticeable reduction in pain. These positive results provided early evidence supporting the potential of tDCS as a therapeutic approach for fibromyalgia and encouraged further trials to explore its broader applications in pain management [126].

**tDCS in Central Neuropathic Pain: Evidence from Spinal Cord Injury**

In 2006, another sham-controlled phase II trial evaluated the effects of tDCS on patients experiencing central pain following traumatic spinal cord injury. Participants were randomized into two groups, one receiving sham stimulation and the other active motor cortex tDCS. Pain levels were assessed by a blinded evaluator using a visual analogue scale. Results demonstrated a significant reduction in pain among patients who received active stimulation, suggesting that this cortical neuromodulation technique holds promise as an effective approach for managing pain associated with spinal cord injuries [127].

**tDCS in the Management of Chronic Migraine**

In 2012, a randomized clinical trial investigated the analgesic effects of tDCS on patients with chronic migraines. A high-resolution computational model was used to assess current flow through brain regions involved in pain perception. Patients were randomized to receive either sham or active tDCS, with each group undergoing 10 sessions of 20 minutes at 2 mA over four weeks. Pain data were collected at baseline, during treatment, and follow-up. Results showed that tDCS produced a delayed but significant improvement in migraine symptoms, likely due to modulation of cortical and subcortical structures such as the brainstem, insula, cingulate cortex, and thalamus [128].

That same year, DaSilva and colleagues further explored tDCS in migraine patients, focusing on motor cortex stimulation. Their findings demonstrated that tDCS altered nociceptive thresholds and reduced pain intensity. A proposed mechanism involved modulation of the periaqueductal gray (PAG), a central hub in the descending pain control system, as well as corticospinal pathways. These effects were attributed to synaptic plasticity, leading to long-term changes in pain processing [129].

More recent systematic reviews have supported the use of tDCS as a non-pharmacological option for chronic migraine, particularly when conventional therapies prove ineffective. Evidence suggests that both anodal and cathodal tDCS, especially when applied to motor or prefrontal cortices, can reduce migraine frequency and severity. Standard protocols typically involve 2 mA stimulation for 20-minute sessions [130-131].

**tDCS for Neuropathic Pain**

In 2018, a systematic review evaluated the effects of tDCS on neuropathic pain by analyzing studies published over the previous five years using keywords such as neuropathic pain, neuralgia, and nerve pain, including both central and peripheral cases. Most studies reported a positive impact of tDCS on neuropathic pain, with the exception of one case involving spinal cord injury. However, due to the overall low quality of the studies and variability in results, no definitive conclusion could be drawn [132].

**tDCS in Post-Stroke Rehabilitation**

Transcranial direct current stimulation (tDCS) has been investigated for its role in post-stroke rehabilitation, targeting both motor function and gait recovery. Research indicates that tDCS can support the recovery of upper limb motor function. For instance, a randomized controlled trial applied tDCS to the dorsolateral prefrontal cortex and cerebellar cortex in stroke patients, resulting in significant improvements in motor performance over time [133].

Additionally, tDCS has shown potential in addressing post-stroke gait abnormalities. A thorough review of multiple studies reported enhancements in walking speed, endurance, and overall mobility, especially when combined with physiotherapy. Nevertheless, the current evidence is rated as

moderate to low, highlighting the need for larger, high-quality trials to confirm these findings [134].

**Mechanisms of tDCS in Pain Modulation**

Frengni and Boggio (2011) reviewed the mechanisms by which tDCS modulates pain, highlighting its effects on different cortical areas. They reported that stimulation of the motor cortex (M1) and dorsolateral prefrontal cortex (dlPFC) increases activity in regions of the pain matrix, including the anterior cingulate cortex and thalamus. Anodal tDCS over M1 is thought to enhance the brain's top-down inhibitory control, thereby reducing pain perception. Specifically, M1 stimulation likely activates descending inhibitory pathways, dampening nociceptive signals sent from the body to the brain. Additionally, tDCS modulates neurotransmitters such as GABA, glutamate, and serotonin, all of which play key roles in pain processing [135].

Polanía (2012) examined anodal and cathodal stimulation of the motor cortex and observed that anodal stimulation increased connectivity within corticostriatal and thalamocortical circuits, whereas cathodal stimulation decreased it, demonstrating the distinct effects of electrode polarity on neural connectivity [136].

Vaseghi *et al*. (2014) investigated tDCS effects on central pain mechanisms and its interactions with the autonomic nervous system. They suggested that tDCS not only reduces pain perception but also influences sympathetic and parasympathetic balance, further modulating pain intensity. The study proposed that tDCS can normalize abnormal thalamocortical oscillations observed in chronic pain states, with M1 stimulation affecting downstream regions involved in both sensory and emotional components of pain [137].

**tDCS Device, Application, and Mechanisms in Pain Modulation**

Transcranial direct current stimulation (tDCS) is a small, battery-powered device with a control panel that allows the operator to adjust the duration and intensity of stimulation. The device is connected to two electrodes, which are attached to the head and usually secured with an elastic strap. Professional-grade stimulators include features such as impedance and current meters to ensure stimulation is both safe and reliable. Proper preparation of the skin and electrodes is essential to maintain low-resistance contact. Electrode size also affects stimulation: smaller electrodes provide more focused stimulation, while larger electrodes cover the entire target region [138]. Incorrect electrode placement can stimulate unintended areas, potentially leading to inaccurate results [139].

Typically, one electrode is positioned over the site of interest, while the reference electrode completes the circuit by being placed on the opposite side of the body, such as the neck or shoulder [139]. Many tDCS devices allow for gradual ramping of current, minimizing discomfort during the session. Once the session starts, the current runs for the pre-set duration and then automatically shuts off [140].

tDCS can be delivered as anodal, cathodal, or sham stimulation. Anodal tDCS increases neuronal excitability in the targeted region, while cathodal stimulation decreases excitability. Sham stimulation serves as a control, delivering a brief current before turning off to mimic the sensation without producing physiological effects [141].

Functional imaging studies have shown that tDCS applied over the motor cortex enhances connectivity among pain-processing brain regions, including the thalamus, insula, and prefrontal cortex. This increased connectivity correlates with reductions in sensory, emotional, and cognitive aspects of pain. tDCS appears to facilitate top-down pain modulation, particularly through the prefrontal cortex. Additionally, volumetric MRI studies suggest tDCS may induce structural changes, such as increased grey matter in pain-related regions, which could provide long-term benefits beyond symptom relief [142,143].

The mechanisms by which tDCS reduces pain can be summarized as follows:

**Modulation of cortical excitability:** Anodal tDCS increases excitability in targeted regions, whereas cathodal tDCS decreases excitability in overactive areas.

**Alteration of thalamocortical circuits:** tDCS modifies pain signal transmission from the thalamus to the cortex, reducing pain intensity.

**Neurotransmitter modulation:** tDCS influences levels of pain-related neurotransmitters, including endorphins, GABA, and serotonin, which play key roles in pain perception and modulation.

**Synaptic plasticity:** Repeated tDCS sessions can produce long-term changes in synaptic strength, leading to sustained pain relief.

**tDCS Functional Mechanisms and Cortical Effects**

In 2017, a single-blinded crossover study investigated functional activity changes produced by tDCS over the primary motor cortex and dorsolateral prefrontal cortex (dlPFC) to examine the functional connectivity of the thalamocortical network, a key site of the pain matrix. The study found that stimulation of the dlPFC produced stronger effects, highlighting its significant role in pain modulation and perception [144].

Transcranial direct current stimulation devices operate by delivering weak electrical currents through electrodes, which modulate neuronal activity and produce long-lasting cortical excitability [141,145]. Anodal tDCS (positive stimulation) depolarizes the resting membrane potential, increasing neuronal excitability and promoting greater cell firing. Conversely, cathodal tDCS hyperpolarizes the membrane potential, decreasing excitability and reducing cell firing. Importantly, tDCS produces subthreshold electrical fields that modulate neuronal activity without directly triggering action potentials.

tDCS also influences neurotransmitter systems, decreasing GABA levels while increasing neurotrophic factors, including glutamate and glutamine. Proton magnetic resonance spectroscopy (MRS) studies have demonstrated that anodal tDCS increases glutamate and glutamine (Glx) concentrations beneath the electrode, with individual differences in Glx predicting changes in network connectivity and effects on remote brain regions [138].

Moreover, tDCS can maintain cortical changes even after stimulation ends, with the duration of these effects depending on the intensity and length of the stimulation. This property supports its potential use in managing neurophysiological disorders, although further research is needed for validation and clinical approval [146].

**Mechanisms and Clinical Potential of Preemptive tDCS in Pain Management**

The analgesic effects of transcranial direct current stimulation (tDCS) involve complex neurophysiological mechanisms, including modulation of cortical excitability, altered connectivity within pain-related networks, and changes in neurotransmitter release. Nitsche (2008) reviewed these mechanisms, highlighting that anodal tDCS increases cortical excitability by depolarizing neurons. In the context of pain, stimulation of the primary motor cortex (M1) and dorsolateral prefrontal cortex (dlPFC) influences downstream pain processing networks, particularly via the descending inhibitory pathways, and engages endogenous opioidergic and dopaminergic systems [147].

The M1 and dlPFC are particularly promising targets for preemptive tDCS due to their established roles in pain modulation. The dlPFC regulates affective states, including the emotional dimension of pain, while supporting cognitive functions such as working memory and planning [148]. Stimulation of the dlPFC has been shown to raise pain thresholds in healthy subjects [149] and reduce chronic pain in fibromyalgia patients [150-151]. The M1, though primarily involved in motor control, modulates pain perception and behavioral responses to painful stimuli. Chronic pain conditions induce changes in M1 activity, and modulating this activity has demonstrated analgesic effects [152].

Preemptive tDCS over M1 and dlPFC provides a proactive approach to pain management, aiming to reduce susceptibility to chronic pain before nociceptive input escalates. This strategy may decrease reliance on pharmacological analgesics, minimizing risks of tolerance and side effects, and could be particularly beneficial for patients at high risk of chronic pain, such as those undergoing surgery, childbirth, or chemotherapy [153].

**Safety and Side Effects of tDCS**

As of 2017, typical tDCS protocols involved stimulation lasting up to 60 minutes with currents of up to 4 mA for two weeks. Reported side effects were generally minor and limited to the electrode site, including temporary skin rash, itching, and tingling. Other mild effects such as headache, nausea, and dizziness were also observed but occurred at similar rates in sham (placebo) stimulation groups. Improper tDCS application can lead to additional effects, such as phosphenes—a temporary, harmless flash of light if electrodes are near the eyes—or standard skin burns. The long-term side effects of extended treatment were still unknown at that time. Nausea is most commonly associated with electrode placement above the mastoid for vestibular system stimulation [154].

There is no scientific evidence indicating lasting or irreversible injury from tDCS. The British National Institute for Health and Care Excellence (NICE) reported no major safety concerns when tDCS was used for depression [140]. Individuals with seizure susceptibility, such as those with epilepsy, are advised against receiving tDCS [154]. Long-term studies also confirm its safety when proper protocols are followed—typically low-intensity stimulation (1-2 mA) for limited session durations [155-156]. Animal studies indicate that brain lesions occur only at current densities over two orders of magnitude higher than commonly used protocols [157].

In 2020, a systematic review and meta-analysis evaluated tDCS for fibromyalgia pain. It concluded that tDCS is generally safe and effective; however, due to high risk of bias and variability among studies, further well-designed research is needed to reach definitive conclusions [158].

**Conclusion and future direction: tDCS as a Potential Modality for Postoperative Endodontic Pain**

Overall, transcranial direct current stimulation (tDCS) represents a promising non-invasive neuromodulation technique, capable of modulating cortical excitability and central pain pathways. Current evidence suggests that tDCS can reduce hyperalgesia and enhance endogenous analgesic mechanisms. However, variability in stimulation protocols and individual patient responses highlights the need for further research to establish standardized, procedure-specific guidelines for clinical implementation.

Given that postoperative endodontic pain remains a significant clinical challenge despite optimized local anesthesia and pharmacological interventions, introducing tDCS into the dental field offers a potential complementary approach. Evaluating the efficacy of tDCS in modulating postoperative endodontic pain could expand the translational application of neuromodulation in dentistry and provide a deeper understanding of central mechanisms underlying acute dental pain. This approach may ultimately improve patient outcomes and contribute to more comprehensive, multimodal pain management strategies in endodontics.

**Conflict of Interest**

Not available

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Not available

**References**

1. Guevara Perez SV, de la Rosa Castolo G, Thollon L, Behr M. A 3D characterization method of geometric variation in edentulous mandibles. Morphologie. 2018;102:255-262.
2. Sathorn C, Parashos P, Messer H. The prevalence of postoperative pain and flare-up in single- and multiple-visit endodontic treatment: a systematic review. Int Endod J. 2008;41:91-99. doi:10.1111/j.1365-2591.2007.01316.x
3. Di Spirito F, Scelza G, Fornara R, Giordano F, Rosa D, Amato A, *et al*. Post-operative endodontic pain management: an overview of systematic reviews on post-operatively administered oral medications and integrated evidence-based clinical recommendations. Healthcare (Basel). 2022;10:760. doi:10.3390/healthcare10050760
4. Pinto CB, Teixeira Costa B, Duarte D, Fregni F. Transcranial direct current stimulation as a therapeutic tool for chronic pain. J ECT. 2018;34(3):e36-e50. doi:10.1097/YCT.0000000000000518
5. Sessle BJ. Recent developments in pain research: central mechanisms of orofacial pain and its control. J Endod. 1986;12(10):435-444.
6. Lipton J, Ship J, Larach-Robinson D. Estimated prevalence and distribution of reported orofacial pain in the United States. J Am Dent Assoc. 1993;124(10):115-121.
7. Estrela C, Guedes OA, Silva JA, Leles CR, Estrela CR, Pécora JD, *et al*. Diagnostic and clinical factors associated with pulpal and periapical pain. Braz Dent J. 2011;22:306-311.
8. Henry MA, Hargreaves KM. Peripheral mechanisms of odontogenic pain. Dent Clin North Am. 2007;51(1):19-

44. doi:10.1016/j.cden.2006.09.007
9. Bergenholtz G, Hørsted-Bindslev P, Reit C. Textbook of endodontology. 2nd ed. Oxford: Wiley-Blackwell; 2010. p.33-35.
10. Ingle JI, Bakland LK, Baumgartner JC. Ingle's endodontics. 6th ed. Ontario: BC Decker; 2008. p.136-137.
11. Hucho T, Levine JD. Signaling pathways in sensitization: toward a nociceptor cell biology. Neuron. 2007;55(3):365-376. doi:10.1016/j.neuron.2007.07.008
12. Närhi MV, Hirvonen TJ, Hakumäki MO. Responses of intradental nerve fibres to stimulation of dentine and pulp. Acta Physiol Scand. 1982;115:173-178. doi:10.1111/j.1748-1716.1982.tb07062.x
13. Närhi M, Jyväsjärvi E, Virtanen A, Huopaniemi T, Ngassapa D, Hirvonen T, *et al*. Role of intradental A- and C-type nerve fibres in dental pain mechanisms. Proc Finn Dent Soc. 1992;88(Suppl 1):507-516.
14. Matthews B, Vongsavan N. Interactions between neural and hydrodynamic mechanisms in dentine and pulp. Arch Oral Biol. 1994;39(Suppl):87S-95S. doi:10.1016/0003-9969(94)90193-7
15. Pashley DH. Mechanisms of dentin sensitivity. Dent Clin North Am. 1990;34:449-473.
16. Vongsavan N, Matthews B. The relationship between the discharge of intradental nerves and the rate of fluid flow through dentine in the cat. Arch Oral Biol. 2007;52:640-647. doi:10.1016/j.archoralbio.2006.12.019
17. Braennstroem M, Astroem A. A study on the mechanism of pain elicited from the dentin. J Dent Res. 1964;43:619-625. doi:10.1177/00220345640430041601
18. Hargreaves KM, Goodis HE, Seltzer S. Seltzer and Bender's dental pulp. Chicago (IL): Quintessence; 2002. p.148-150.
19. Närhi MV. The characteristics of intradental sensory units and their responses to stimulation. J Dent Res. 1985;64(Spec No):564-571. doi:10.1177/002203458506400411
20. van Wijk AJ, Hoogstraten J. Reducing fear of pain associated with endodontic therapy. Int Endod J. 2006;39(5):384-388. doi:10.1111/j.1365-2591.2006.01090.x
21. van Wijk AJ, Duyx MPMA, Hoogstraten J. The effect of written information on pain experience during periodontal probing. J Clin Periodontol. 2004;31(4):282-285. doi:10.1111/j.1600-051X.2004.00480.x
22. Levin L, Amit A, Ashkenazi M. Post-operative pain and use of analgesic agents following various dental procedures. Am J Dent. 2006;19(4):245-247.
23. Ashkenazi M, Blumer S, Eli I. Post-operative pain and use of analgesic agents in children following intrasulcular anaesthesia and various operative procedures. Br Dent J. 2007;202(5):E13. doi:10.1038/bdj.2007.81
24. Tsesis I, Faivishevsky V, Fuss Z, Zukerman O. Flare-ups after endodontic treatment: a meta-analysis of literature. J Endod. 2008;34(10):1177-1181. doi:10.1016/j.joen.2008.07.016
25. Iqbal A. The factors responsible for endodontic treatment failure in the permanent dentitions of the patients reported to the College of Dentistry, University of Aljouf, Kingdom of Saudi Arabia. J Clin Diagn Res. 2016;10:146-148. doi:10.7860/JCDR/2016/14272.7884
26. Gotler M, Bar-Gil B, Ashkenazi M. Postoperative pain after root canal treatment: a prospective cohort study. Int J Dent. 2012;2012:310467. doi:10.1155/2012/310467
27. Iranmanesh F, Parirokh M, Haghdoost AA, Abbott PV. Effect of corticosteroids on pain relief following root canal treatment: a systematic review. Iran Endod J. 2017;12:123-130. doi:10.22037/iej.2017.26
28. Nelson Filho P, Silva LA, Leonardo MR, Utrilla LS, Figueiredo F, *et al*. Connective tissue responses to calcium hydroxide-based root canal medicaments. Int Endod J. 1999;32(4):303-311. doi:10.1046/j.1365-2591.1999.00225.x
29. Gondim E, Setzer FC, Dos Carmo CB, Kim S. Postoperative pain after the application of two different irrigation devices in a prospective randomized clinical trial. J Endod. 2010;36:1295-1301. doi:10.1016/j.joen.2010.04.012
30. Smith EA, Marshall JG, Selph SS, Barker DR, Sedgley CM. Nonsteroidal anti-inflammatory drugs for managing postoperative endodontic pain in patients who present with preoperative pain: a systematic review and meta-analysis. J Endod. 2016;43:7-15. doi:10.1016/j.joen.2016.09.010
31. Gomes M, Böttcher D, Scarparo R, Morgental R, Waltrick S, Ghisi A, *et al*. Predicting pre- and postoperative pain of endodontic origin in a southern Brazilian subpopulation: an electronic database study. Int Endod J. 2016;49:XXX-XXX. doi:10.1111/iej.12684
32. Sipavičiūtė E, Manelienė R. Pain and flare-up after endodontic treatment procedures. Stomatologija. 2014;16(1):25-30.
33. Siqueira JF, Rôças IN, Favieri A, Machado AG, Gahyva SM, Oliveira JC, *et al*. Incidence of postoperative pain after intracanal procedures based on an antimicrobial strategy. J Endod. 2002;28:457-460. doi:10.1097/00004770-200206000-00010
34. Alonso-Ezpeleta LO, Gasco-Garcia C, Castellanos-Cosano L, Martín-González J, López-Frías FJ, Segura-Egea JJ. Postoperative pain after one-visit root-canal treatment on teeth with vital pulps: comparison of three different obturation techniques. Med Oral Patol Oral Cir Bucal. 2012;17:e721-e727. doi:10.4317/medoral.17898
35. Khasnis SA, Kidiyoor KH, Patil AB, Kenganal SB. Vertical root fractures and their management. J Conserv Dent. 2014;17(2):103-110. doi:10.4103/0972-0707.128034
36. Neaverth EJ. Disabling complications following inadvertent overextension of a root canal filling material. J Endod. 1989;15:135-139. doi:10.1016/S0099-2399(89)80136-0
37. Segura-Egea JJ, Jiménez-Pinzón A, Poyato-Ferrera M, Velasco-Ortega E, Ríos-Santos JV. Periapical status and quality of root fillings and coronal restorations in an adult Spanish population. Int Endod J. 2004;37:525-530. doi:10.1111/j.1365-2591.2004.00826.x
38. Sjögren U, Figdor D, Persson S, Sundqvist G. Influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with apical periodontitis. Int Endod J. 1997;30:297-306. doi:10.1046/j.1365-2591.1997.00092.x
39. Nair PN. On the causes of persistent apical periodontitis: a review. Int Endod J. 2006;39(4):249-281. doi:10.1111/j.1365-2591.2006.01099.x
40. Owatz CB, Khan AA, Schindler WG, Schwartz SA, Keiser K, Hargreaves KM, *et al*. The incidence of mechanical allodynia in patients with irreversible pulpitis. J Endod. 2007;33:552-556. doi:10.1016/j.joen.2007.01.023

41. Parirokh M, Rekabi AR, Ashouri R, Nakhaee N, Abbott PV, Gorjestani H, *et al*. Effect of occlusal reduction on postoperative pain in teeth with irreversible pulpitis and mild tenderness to percussion. J Endod. 2013;39:1-5. doi:10.1016/j.joen.2012.08.008
42. Emara RS, Abou El Nasr HM, El Boghdadi RM. Evaluation of postoperative pain intensity following occlusal reduction in teeth associated with symptomatic irreversible pulpitis and symptomatic apical periodontitis: a randomized clinical study. Int Endod J. 2019;52:288-296. doi:10.1111/iej.13012
43. Ahmed YE, Ahmed GM, Ibrahim MM, Hashem AA, El-Batouty KM, Abu-El Sadat SM, *et al*. Post-treatment endodontic pain following occlusal reduction in mandibular posterior teeth with symptomatic irreversible pulpitis and sensitivity to percussion: a single centre randomized controlled trial. Int Endod J. 2020;53:1170-1180. doi:10.1111/iej.13328
44. Sadaf D, Ahmad MZ. Factors associated with postoperative pain in endodontic therapy. Int J Biomed Sci. 2014;10(4):243-247.
45. Georgopoulou M, Anastassiadis P, Sykaras S. Pain after chemomechanical preparation. Int Endod J. 1986;19(6):309-314. doi:10.1111/j.1365-2591.1986.tb00495.x
46. Unruh AM, Ritchie J, Merskey H. Does gender affect appraisal of pain and pain coping strategies? Clin J Pain. 1999;15:31-40. doi:10.1097/00002508-199903000-00006
47. Liddell A, Locker D. Gender and age differences in attitudes to dental pain and dental control. Community Dent Oral Epidemiol. 1997;25(4):314-318. doi:10.1111/j.1600-0528.1997.tb00945.x
48. Shabbir J, Khurshid Z, Qazi F, Sarwar H, Afaq H, Salman S, *et al*. Effect of different host-related factors on postoperative endodontic pain in necrotic teeth dressed with interappointment intracanal medicaments: a multicomparison study. Eur J Dent. 2021;15:152-157. doi:10.1055/s-0040-1721909
49. Yesilsoy C, Koren LZ, Morse DR, Rankow H, Bolanos OR, Furst ML, *et al*. Post-endodontic obturation pain: a comparative evaluation. Quintessence Int. 1988;19(6):431-438.
50. Polycarpou N, Ng YL, Canavan D, Moles DR, Gulabivala K. Prevalence of persistent pain after endodontic treatment and factors affecting its occurrence in cases with complete radiographic healing. Int Endod J. 2005;38(3):169-178. doi:10.1111/j.1365-2591.2004.00923.x
51. Segura-Egea JJ, Cisneros-Cabello R, Llamas-Carreras JM, Velasco-Ortega E. Pain associated with root canal treatment. Int Endod J. 2009;42(7):614-620. doi:10.1111/j.1365-2591.2009.01562.x
52. Qualtrough AJ, Whitworth JM, Dummer PM. Preclinical endodontology: an international comparison. Int Endod J. 1999;32(5):406-414.
53. El Mubarak AH, Abu-Bakr NH, Ibrahim YE. Postoperative pain in multiple-visit and single-visit root canal treatment. J Endod. 2010;36(1):36-39. doi:10.1016/j.joen.2009.09.003
54. Fonseca B, Coelho MS, Bueno CEDS, Fontana CE, Martin AS, Rocha DGP, *et al*. Assessment of extrusion and postoperative pain of a bioceramic and resin-based root canal sealer. Eur J Dent. 2019;13:343-348. doi:10.1055/s-0039-3399457
55. Goreva LA, Petrikas A. Postobturation pain associated with endodontic treatment. Stomatologiia (Mosk). 2004;83(2):14-16.
56. Siqueira JF Jr, Rôças IN, Favieri A, Machado AG, Oliveira JC, Gahyva SM, *et al*. Incidence of postoperative pain after intracanal procedures based on an antimicrobial strategy. J Endod. 2002;28(6):457-460. doi:10.1097/00004770-200206000-00010
57. Gatchel RJ. Managing anxiety and pain during dental treatment. J Am Dent Assoc. 1992;123(6):37-41. doi:10.14219/jada.archive.1992.0194
58. Keiser K, Hargreaves KM. Building effective strategies for the management of endodontic pain. Endod Topics. 2002;3(1):93-105.
59. Jackson DL, Moore PA, Hargreaves KM. Preoperative nonsteroidal anti-inflammatory medication for the prevention of postoperative dental pain. J Am Dent Assoc. 1989;119:641-646.
60. Khan A, Dionne RA. *In vivo* selectivity of a selective COX-2 inhibitor in the oral surgery model. Clin Pharmacol Ther. 2002;72:44-49.
61. Dionne RA. Suppression of dental pain by the preoperative administration of flurbiprofen. Am J Med. 1986;80(5):41-47.
62. Moore PA, Werther JR, Seldin EB, Stevens CM. Analgesic regimens for third molar surgery: pharmacologic and behavioral considerations. J Am Dent Assoc. 1986;113(5):739-743.
63. Doroschak AM, Bowles WR, Hargreaves KM. Evaluation of the combination of flurbiprofen and tramadol for management of endodontic pain. J Endod. 1999;25(9):660-663.
64. Vane JR. Inhibition of prostaglandin synthesis as a mechanism of action for aspirin-like drugs. Nat New Biol. 1971;231(25):232-235.
65. Bushra R, Aslam N. An overview of clinical pharmacology of ibuprofen. Oman Med J. 2010;25(3):155-166.
66. Harirforoosh S, Asghar W, Jamali F. Adverse effects of nonsteroidal anti-inflammatory drugs: an update of gastrointestinal, cardiovascular, and renal complications. J Pharm Pharm Sci. 2013;16(5):821-847. doi:10.18433/j3vw2f.
67. Alhammadi N, Asiri AH, Alshahrani FM, *et al*. Gastrointestinal complications associated with non-steroidal anti-inflammatory drug use among adults: a retrospective, single-center study. Cureus. 2022;14(6):e26154. doi:10.7759/cureus.26154.
68. Peura DA, Goldkind L. Balancing the gastrointestinal benefits and risks of nonselective NSAIDs. Arthritis Res Ther. 2005;7(Suppl 4):S0-S13. doi:10.1186/ar1793.
69. Lee YS, Kim H, Brahim JS, Rowan J, Lee G, Dionne RA. Acetaminophen selectively suppresses peripheral prostaglandin E2 release and increases COX-2 gene expression in a clinical model of acute inflammation. Pain. 2007;129(3):279-286.
70. Anderson BJ. Paracetamol (acetaminophen): mechanisms of action. Paediatr Anaesth. 2008;18(10):915-921.
71. American Geriatrics Society Panel on Pharmacological Management of Persistent Pain in Older Persons. Pharmacological management of persistent pain in older persons. J Am Geriatr Soc. 2009;57(8):1331-1346.
72. Douglas DR, Sholar JB, Smilkstein MJ. A pharmacokinetic comparison of acetaminophen products (Tylenol Extended Relief vs regular Tylenol). Acad Emerg Med. 1996;3(8):740-744.

73. Rood JP, Pateromichelakis S. Inflammation and peripheral nerve sensitisation. Br J Oral Surg. 1981;19(1):67-72.
74. Roy ML, Narahashi T. Differential properties of tetrodotoxin-sensitive and tetrodotoxin-resistant sodium channels in rat dorsal root ganglion neurons. J Neurosci. 1992;12(6):2104-2111.
75. Int Dent J. Efficacy comparison of periapical infiltration injection of dexamethasone, morphine, and placebo for postoperative endodontic pain. Int Dent J. 2020;62(2):74-78. doi:10.1111/j.1875-595X.2011.00092.x.
76. Vane J, Botting R. Inflammation and the mechanism of action of anti-inflammatory drugs. FASEB J. 1987;1(2):89-96.
77. Marshall JG, Walton RE. The effect of intramuscular injection of steroid on posttreatment endodontic pain. J Endod. 1984;10(12):584-588.
78. Campbell WL, Kendrick RW. Postoperative dental pain - a comparative study of anti-inflammatory and analgesic agents. Ulster Med J. 1991;60(1):39-43.
79. Moore PA. Pain management in dental practice: tramadol vs codeine combinations. J Am Dent Assoc. 1999;130(7):1075-1079.
80. Zanjir M, Sgro A, Lighvan NL, *et al*. Efficacy and safety of postoperative medications in reducing pain after nonsurgical endodontic treatment: a systematic review and network meta-analysis. J Endod. 2020;46(10):1387-1402.e4.
81. Pak JG, White SN. Pain prevalence and severity before, during, and after root canal treatment: a systematic review. J Endod. 2011;37(4):429-438.
82. Tupyota P, Chailertvanitkul P, Laopaiboon M, *et al*. Supplementary techniques for pain control during root canal treatment of lower posterior teeth with irreversible pulpitis: a systematic review and meta-analysis. Aust Endod J. 2018;44(1):14-25.
83. Khoury JN, Mihailidis S, Ghabriel M, Townsend G. Applied anatomy of the pterygomandibular space: improving the success of inferior alveolar nerve blocks. Aust Dent J. 2011;56(1):112-121.
84. Berggren U, Meynert G. Dental fear and avoidance: causes, symptoms, and consequences. J Am Dent Assoc. 1984;109(2):247-251.
    85-92. [Anesthesia efficacy studies: Aggarwal, Goldberg, Shapiro, Drum, Mikesell].
85. Nagendrababu V, Abbott PV, Pulikkotil SJ, *et al*. Comparing the anaesthetic efficacy of 1.8 mL and 3.6 mL of anaesthetic solution for inferior alveolar nerve blocks for teeth with irreversible pulpitis: a systematic review and meta-analysis with trial sequential analysis. Int Endod J. 2021;54(3):331-342.
86. Knuf K, Maani CV. Nitrous Oxide. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025. Available from: https://www.ncbi.nlm.nih.gov/books/NBK532922/.
87. Silva IA, Agnol Júnior CAD, Weissheimer T, *et al*. Pharmacological management of anxiety on pain occurrence during root canal treatment: a systematic review. Eur Endod J. 2023;8(2):105-113.
88. Riaz M, Zafar F, Khalid Z, *et al*. Comparison of preoperative analgesics on the efficacy of inferior alveolar nerve block in patients with symptomatic irreversible pulpitis: a double-blinded, randomized controlled trial. Eur Endod J. 2023;8(3):246-252.
89. Xiqian L, Ying Z, Mian M. The effect of apical patency on postoperative pain following endodontic therapy: a systematic review and meta-analysis. Eur J Oral Sci. 2024;132(2):e12986.
90. Kashefinejad M, Harandi A, Eram S, Bijani A. Comparison of single-visit post endodontic pain using Mtwo rotary and hand K-file instruments: a randomized clinical trial. J Dent (Tehran). 2016;13(1):10-17.
91. Noorollayouni A, Lotfi M, Shahi S, Rahimi S, Noorollayouni S, Milani AS. Postoperative pain after endodontic treatment of mandibular molars with two different instrumentation techniques: a randomized clinical trial. Dent Res J (Isfahan). 2023;20(2):83-90.
92. Ahmad MZ, Sadaf D, Merdad KA, Almohaimeed A, Onakpoya IJ. Calcium hydroxide as an intracanal medication for postoperative pain during primary root canal therapy: a systematic review and meta-analysis with trial sequential analysis of randomised controlled trials. J Evid Based Dent Pract. 2022;22:101680.
93. Wagh KS, Warhadpande MM, Dakshindas DM. Prevalence of endodontic flare-up following intracanal medicament placement in permanent teeth undergoing endodontic treatment—a systematic review. J Conserv Dent. 2022;25:3-8.
94. Alkhamsan RA, Aldaiji RAA, Aldhahri AA, Alsaljah WS, Alotaibi AF, Alqahtani K, *et al*. Efficacy of antibiotics and steroids as intra-canal medicament in endodontics: a systematic review. Ann Dent Specialty. 2023;11:35-42.
95. Hegde V, Jain A, Patekar SB. Comparative evaluation of calcium hydroxide and other intracanal medicaments on postoperative pain in patients undergoing endodontic treatment: a systematic review and meta-analysis. J Conserv Dent. 2023;26:134-142. doi:10.4103/jcd.jcd_501_22.
96. Alkhamsan RA, Aldaiji RAA, Aldhahri AA, Alsaljah WS, Alotaibi AF, Alqahtani K, *et al*. Efficacy of antibiotics and steroids as intra-canal medicament in endodontics: a systematic review. Ann Dent Specialty. 2023;11:35-42.
97. Ismail HH, Obeid M, Hassanien E. Efficiency of diode laser in control of post-endodontic pain: a randomized controlled trial. Clin Oral Investig. 2023;27:2797-2804.
98. Mohamed AA, El-Kenany MH, Salem RH, Yousry MM. Effectiveness of two intracanal irrigation solutions delivered through cryotherapy on postoperative endodontic pain: a randomized clinical trial. Egypt Dent J. 2024;70:123-130.
99. Vera J, Ochoa J, Vazquez-Carcaño M, *et al*. Effect of intracanal cryotherapy on reducing root surface temperature. J Endod. 2015;41:1884-1887.
100. Keskin C, Özdemir Ö, Uzun İ, Güler B. Effect of intracanal cryotherapy on pain after single-visit root canal treatment. Aust Endod J. 2017;43:83-88.
101. Jamali S, Darvish M, Nasrabadi N, Jafarizadeh S. Evaluation of the effect of the intensity and occurrence of postoperative pain of resin-based and bioceramic root canal sealers: a systematic review and meta-analysis of randomized controlled trial studies. Pesqui Bras Odontopediatria Clin Integr. 2021;21:e0219.
102. Mekhdieva E, Del Fabbro M, Alovisi M, Comba A, Scotti N, Tumedei M, *et al*. Postoperative pain following root canal filling with bioceramic vs traditional filling techniques: a systematic review and meta-analysis of randomized controlled trials. J Clin Med. 2021;10:4509.
103. Nguyen D, Nagendrababu V, Pulikkotil SJ, Rossi-Fedele

G. Effect of occlusal reduction on postendodontic pain: a systematic review and meta-analysis of randomised clinical trials. Aust Endod J. 2020;46:282-294.
104. Wong AW, Zhang C, Chu CH. A systematic review of nonsurgical single-visit versus multiple-visit endodontic treatment. Clin Cosmet Investig Dent. 2014;6:45-56. doi:10.2147/CCIDE.S61487.
105. Harrison JW, Baumgartner JC, Svec TA. Incidence of pain associated with clinical factors during and after root canal therapy. Part 2. Postobturation pain. J Endod. 1983;9:434-438. doi:10.1016/S0099-2399(83)80259-3.
106. Al-Negrish AR, Habahbeh R. Flare-up rate related to root canal treatment of asymptomatic pulpally necrotic central incisor teeth in patients attending a military hospital. J Dent. 2006;34:635-640. doi:10.1016/j.jdent.2005.12.007.
107. Pak JG, White SN. Pain prevalence and severity before, during, and after root canal treatment: a systematic review. J Endod. 2011;37:429-438. doi:10.1016/j.joen.2010.12.016.
108. Seltzer S, Bender IB, Ehrenreich J. Incidence and duration of pain following endodontic therapy. Relationship to treatment with sulfonamides and to other factors. Oral Surg Oral Med Oral Pathol. 1961;14:74-82. doi:10.1016/0030-4220(61)90476-5.
109. Siqueira JF Jr. Microbial causes of endodontic flare-ups. Int Endod J. 2003;36:453-463. doi:10.1046/j.1365-2591.2003.00671.x.
110. Rosenberg PA. Clinical strategies for managing endodontic pain. Endod Top. 2002;3:78-92. doi:10.1034/j.1601-1546.2002.30107.x.
111. Mehlisch DR. The efficacy of combination analgesic therapy in relieving dental pain. J Am Dent Assoc. 2002;133:861-871. doi:10.14219/jada.archive.2002.0300.
112. Desmeules J, Rollason V, Piguet V, Dayer P. Clinical pharmacology and rationale of analgesic combinations. Eur J Anaesthesiol Suppl. 2003;20:7-11.
113. Woods AJ, Antal A, Bikson M, Boggio PS, Brunoni AR, Celnik P, *et al*. A technical guide to tDCS and related non-invasive brain stimulation tools. Clin Neurophysiol. 2016;127:1031-1048.
114. Kronberg G, Rahman A, Sharma M, Bikson M, Parra LC. Direct current stimulation boosts Hebbian plasticity *in vitro*. Brain Stimul. 2020;13:287-301.
115. Arul-Anandam AP, Loo C, Sachdev P. Transcranial direct current stimulation—what is the evidence for its efficacy and safety? F1000 Med Rep. 2009;1:58.
116. DaSilva AF, Mendonca ME, Zaghi S, Lopes M, DosSantos MF, Spierings EL, *et al*. tDCS-induced analgesia and electrical fields in pain-related neural networks in chronic migraine. Headache. 2012;52:1283-1295.
117. Fregni F, Gimenes R, Valle AC, Ferreira MJ, Rocha RR, Natalle L, *et al*. A randomized, sham-controlled, proof-of-principle study of transcranial direct current stimulation for the treatment of pain in fibromyalgia. Arthritis Rheum. 2006;54:3988-3995. doi:10.1002/art.22195.
118. Fregni F, Boggio PS, Lima MC, *et al*. A sham-controlled, phase II trial of transcranial direct current stimulation for the treatment of central pain in traumatic spinal cord injury. Pain. 2006;122:197-209. doi:10.1016/j.pain.2006.02.023.
119. Chiriac VF, Leucuța DC, Moșoiu DV. Pain and transcranial direct current stimulation: a bibliometric analysis. J Pain Res. 2023;16:3655-3667. doi:10.2147/JPR.S427658.
120. Azarkolah A, Noorbala AA, Ansari S, Hallajian AH, Salehinejad MA. Efficacy of transcranial direct current stimulation on pain level and disability of patients with fibromyalgia: a systematic review of randomized controlled trials with parallel-group design. Brain Sci. 2023;14:26. doi:10.3390/brainsci14010026.
121. Polanía R, Paulus W, Nitsche MA. Modulating cortico-striatal and thalamo-cortical functional connectivity with transcranial direct current stimulation. Hum Brain Mapp. 2012;33:2499-2508.
122. Sankarasubramanian V, Cunningham DA, Potter-Baker KA, Beall EB, Roelle SM, Varnerin NM, *et al*. Transcranial direct current stimulation targeting primary motor versus dorsolateral prefrontal cortices: proof-of-concept study investigating functional connectivity of thalamocortical networks specific to sensory-affective information processing. Brain Connect. 2017;7:182-196.
123. Boggio PS, Rocha RR, da Silva MT, Fregni F. Differential modulatory effects of transcranial direct current stimulation on a facial expression go-no-go task in males and females. Neurosci Lett. 2008;447:101-105.
124. Hong P, Liu Y, Wan Y, Xiong H, Xu Y. Transcranial direct current stimulation for migraine: a systematic review and meta-analysis of randomized controlled trials. CNS Neurosci Ther. 2022;28:992-1008. doi:10.1111/cns.13843.
125. Sankarasubramanian V, Cunningham DA, Potter-Baker KA, Beall EB, Roelle SM, Varnerin NM, *et al*. Transcranial direct current stimulation targeting primary motor versus dorsolateral prefrontal cortices: proof-of-concept study investigating functional connectivity of thalamocortical networks specific to sensory-affective information processing. Brain Connect. 2017;7(3):182-196.
126. Nitsche MA, Cohen LG, Wassermann EM, Priori A, Lang N, Antal A, *et al*. Transcranial direct current stimulation: state of the art 2008. Brain Stimul. 2008;1(3):206-223.
127. Allman C, Amadi U, Winkler AM, Wilkins L, Filippini N, Kischka U, *et al*. Ipsilesional anodal tDCS enhances the functional benefits of rehabilitation in patients after stroke. Sci Transl Med. 2016;8(330):330re1.
128. Corominas-Teruel X, Mozo RMSS, Simó MF, Colomina Fosch MT, Valero-Cabré A. Transcranial direct current stimulation for gait recovery following stroke: a systematic review of current literature and beyond. Front Neurol. 2022;13:953939.
129. Fregni F, Gimenes R, Valle AC, *et al*. A randomized, sham-controlled, proof of principle study of transcranial direct current stimulation for the treatment of pain in fibromyalgia. Arthritis Rheum. 2006;54(12):3988-3998.
130. Nitsche MA, Paulus W. Sustained excitability elevations induced by transcranial DC motor cortex stimulation in humans. Neurology. 2001;57(10):1899-1901.
131. Vaseghi B, Zoghi M, Jaberzadeh S. Does anodal transcranial direct current stimulation modulate sensory perception and pain? A meta-analysis study. Clin Neurophysiol. 2014;125(9):1847-1858.
132. Vural G, Soldini A, Padberg F, Karslı B, Zinchenko A, Goerigk S, *et al*. Exploring the effects of prefrontal transcranial direct current stimulation on brain metabolites: a concurrent tDCS-MRS study. Hum Brain Mapp. 2024;45(18):e70097.
133. Naumann RB, Dellinger AM. Mobile device use while

driving—United States and seven European countries, 2011. MMWR Morb Mortal Wkly Rep. 2013;62(10):177-181.
134. Datta A, Bansal V, Diaz J, Patel J, Reato D, Bikson M. Gyri-precise head model of transcranial direct current stimulation: improved spatial focality using a ring electrode versus conventional rectangular pad. Brain Stimul. 2009;2(4):201-207.
135. Lloyd DM, Wittkopf PG, Arendsen LJ, Jones AKP. Is transcranial direct current stimulation (tDCS) effective for the treatment of pain in fibromyalgia? A systematic review and meta-analysis. J Pain. 2020;21(11-12):1085-1100.
136. Utz KS, Dimova V, Oppenländer K, Kerkhoff G. Electrified minds: transcranial direct current stimulation (tDCS) and galvanic vestibular stimulation (GVS) as methods of non-invasive brain stimulation in neuropsychology—a review of current data and future implications. Neuropsychologia. 2010;48(10):2789-2810.
137. Schading S, Pohl H, Gantenbein A, Luechinger R, Sandor P, Riederer F, *et al*. Tracking tDCS induced grey matter changes in episodic migraine: a randomized controlled trial. J Headache Pain. 2021;22(1):139.
138. Hunter MA, Coffman BA, Gasparovic C, Calhoun VD, Trumbo MC, Clark VP. Baseline effects of transcranial direct current stimulation on glutamatergic neurotransmission and large-scale network connectivity. Brain Res. 2015;1594:92-107.
139. Moshfeghinia R, Shekouh D, Mostafavi S, Hosseinzadeh M, Bahadori AR, Abdollahifard S, *et al*. The effects of transcranial direct-current stimulation (tDCS) on pain intensity of patients with fibromyalgia: a systematic review and meta-analysis. BMC Neurol. 2023;23:395.
140. Bikson M, Grossman P, Thomas C, Zannou AL, Jiang J, Adnan T, *et al*. Safety of transcranial direct current stimulation: evidence based update 2016. Brain Stimul. 2016;9(5):641-661.
141. Davidson B, Bhattacharya A, Sarica C, Darmani G, Raies N, Chen R, *et al*. Neuromodulation techniques - from non-invasive brain stimulation to deep brain stimulation. Neurotherapeutics. 2024;21(3):e00330.
142. Petroff OA. GABA and glutamate in the human brain. Neuroscientist. 2002;8(6):562-573.
143. Boggio PS, Rocha RR, da Silva MT, Fregni F. Differential modulatory effects of transcranial direct current stimulation on a facial expression go-no-go task in males and females. Neurosci Lett. 2008;447:101-105.
144. Marlow NM, Bonilha HS, Short EB. Efficacy of transcranial direct current stimulation and repetitive transcranial magnetic stimulation for treating fibromyalgia syndrome: a systematic review. Pain Pract. 2013;13:131-145.
145. Zhu CE, Yu B, Zhang W, Chen WH, Qi Q, Miao Y, *et al*. Effectiveness and safety of transcranial direct current stimulation in fibromyalgia: a systematic review and meta-analysis. J Rehabil Med. 2017;49(1):2-9.
146. Castillo Saavedra L, Mendonca M, Fregni F. Role of the primary motor cortex in the maintenance and treatment of pain in fibromyalgia. Med Hypotheses. 2014;83(3):332-336.
147. Benyamin R, Trescot AM, Datta S, *et al*. Opioid complications and side effects. Pain Physician. 2008;11(2 Suppl):S105-S120.
148. Antal A, Alekseichuk I, Bikson M, Brockmöller J, Brunoni AR, Chen R, *et al*. Low intensity transcranial electric stimulation: safety, ethical, legal regulatory and application guidelines. Clin Neurophysiol. 2017;128(9):1774-1809.
149. Kessler SK, Minhas P, Woods AJ, Rosen A, Gorman C, Bikson M. Dosage considerations for transcranial direct current stimulation in children: a computational modeling study. PLoS One. 2013;8(9):e76112.
150. Mekonnen A, Salvador R, Ruffini G, Miranda PC. The relationship between transcranial current stimulation electrode montages and the effect of the skull orbital openings. Conf Proc IEEE Eng Med Biol Soc. 2012;2012:831-834.
151. Liebetanz D, Koch R, Mayenfels S, König F, Paulus W, Nitsche MA. Safety limits of cathodal transcranial direct current stimulation in rats. Clin Neurophysiol. 2009;120(6):1161-1167.
152. Utz KS, Dimova V, Oppenländer K, Kerkhoff G. Electrified minds: transcranial direct current stimulation (tDCS) and galvanic vestibular stimulation (GVS) as methods of non-invasive brain stimulation in neuropsychology—a review of current data and future implications. Neuropsychologia. 2010;48(10):2789-2810.

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