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Applications Of Tens In Dentistry- Literature Review

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ABSTRACT

In many areas of dentistry, transcutaneous electrical nerve stimulation (TENS) has shown promise as a non-invasive, non-pharmacological pain treatment technique. This literature review examines how TENS is used in dentistry, emphasizing its workings, advantages, drawbacks, and prospects. The main mechanisms by which TENS therapy modifies both acute and chronic pain perception are the Gate Control Theory and the activation of endogenous opioid release. TENS has demonstrated clinical effectiveness in treating orofacial problems in juvenile and special needs populations, including Bell's palsy, trigeminal neuralgia, myofascial pain dysfunction syndrome (MPDS), temporomandibular disorders (TMD), and procedural pain. It can be used for neuromuscular re-education in prosthodontics, procedural analgesia in endodontics and periodontics, and pain related to tooth movement in orthodontics.

Additionally, by improving salivary flow, TENS shows potential in treating xerostomia. It has disadvantages as well as contraindications, particularly for people with epilepsy, pacemakers, and other systemic disorders, despite its advantages of low cost, portability, and little side effects. The ongoing issues with patient education, electrode placement, and dosage control underscore the need for more thorough clinical research and established practices. Transcutaneous Electrical Nerve Stimulation (TENS) demonstrates considerable potential in the future of dental practice due to ongoing technological advancements and the increasing patient preference for non-invasive, home-based therapies. In contrast to conventional pharmacological analgesics, TENS offers a safer and more physiologically compatible modality for the managing dental pain.

1. INTRODUCTION

The noninvasive analgesic method of transcutaneous electrical nerve stimulation (TENS), which applies low-voltage electrical currents to the skin's surface using electrode pads, can treat nociceptive, neuropathic, or musculoskeletal pain. (1–3) TENS is generally employed in the medical field to alleviate acute and chronic pain. (4)

TENS therapy produces Endorphins and other naturally occurring substances that help stimulate sensory nerves, which modifies pain perception. The TENS therapy is founded on the gate control hypothesis for pain, which postulates that non-painful input can "close the gate" to unpleasant input, thus lessening the pain perception. TENS machines can

effectively provide brief relief from various types of pain by preventing or rerouting pain signals from reaching the brain by delivering regulated electrical impulses. TENS machines' intensity, frequency, and pulse duration are usually customizable, enabling users to modify their treatment to their comfort level and the kind of pain they're experiencing. (2)

TENS uses self-adhering conducting pads called electrodes to deliver pulsed electrical currents across the skin's intact surface. A portable pulse generator produces the currents. There is no risk of toxicity, so patients can self-administer TENS and adjust dosage as needed. In the UK, "standard" TENS devices cost about £30 and may be bought without a prescription. (5)

Parts of TENS units:

TENS UNIT: it generates electric pulses. There are two types available:

"Clinical Model": Dentists use this model at the clinic. It connects to the building's electrical outlet to produce electricity.

"Patient Model": Patients can wear this little, portable gadget as part of their outfit, in their pocket, or fasten it to their belt. It has a battery that serves as a power source.

Lead Wires: Enable the electrodes and the TENS unit to connect electronically.

Electrodes: The TENS unit converts the electric flow to an ionic current flow in living tissue through electrodes. It is possible to implant electrodes both within and outside the mouth. There are two types of extraoral electrodes: Flexible electrodes made of silicone rubber impregnated with carbon, which are attached to the skin's surface using an electrically conductive gel and Rigid/self-adhesive electrodes – Often metal or carbon film-based, with built-in adhesive gel for direct skin application. Surgical tape is used to hold them in place. Tin plates or aluminum electrodes that do not fit the body are attached to the skin's surface using cotton pads or sponges that moisten in tap water. Sticky electrodes, clamp electrodes, and cotton roll electrodes are the intraoral electrodes. Sticky electrodes are currently the most widely used electrode kind. (6)

2. TENS for Orofacial Pain Management

Transcutaneous Electrical Nerve Stimulation (TENS) is a non-invasive, drug-free modality widely used for managing orofacial pain, particularly in conditions such as temporomandibular disorders (TMD), myofascial pain dysfunction syndrome (MPDS), trigeminal neuralgia (TN), and procedural dental pain. Its analgesic effects stem from two main mechanisms: the Gate Control Theory, which involves inhibition of nociceptive signals via A-β fiber stimulation, and the activation of descending inhibitory pathways that promote endogenous opioid release such as endorphins and serotonin (7-9).

Bell's Palsy

Bell's Palsy is an idiopathic, unilateral facial nerve paralysis, often associated with inflammation and impaired neuromuscular function. TENS has shown potential in the rehabilitation of facial muscles in Bell's Palsy patients by promoting nerve regeneration, enhancing blood circulation, and preventing muscle atrophy.

TENS is usually applied in the preauricular region, stimulating the facial nerve branches to facilitate muscular re-education. Clinical studies have demonstrated that adjunctive TENS therapy, when combined with conventional facial exercises or physiotherapy, can accelerate recovery, improve facial symmetry, and reduce residual paralysis, particularly in the subacute and chronic stages of Bell's Palsy. One randomized controlled trial reported that patients receiving TENS showed significantly better House-Brackmann facial nerve grading scores after 3 weeks compared to control groups receiving only exercises (10).

Clinical Applications.

Temporomandibular Disorders (TMD):

TENS reduces myoelectric activity in masticatory muscles, leading to improved mandibular function and pain relief. When used alone or with splint therapy, it enhances clinical outcomes in TMD patients (11-13).

Myofascial Pain Dysfunction Syndrome (MPDS):

By stimulating A-δ fibers, TENS promotes muscle relaxation, reduces edema, and enhances local circulation, effectively reducing chronic preauricular pain and muscle fatigue (14,15).

Trigeminal Neuralgia (TN):

In patients with neuropathic facial pain, TENS provides relief by stimulating large fibers and interrupting pain transmission. It offers a non-invasive option for drug-resistant cases (16,17).

Pediatric and Procedural Pain:

TENS serves as a needle-free alternative to local anesthesia in pediatric dentistry, showing comparable efficacy and higher acceptance in children (18,19).

Xerostomia:

Application of TENS over the parotid gland has been shown to stimulate salivary flow in both healthy individuals and xerostomia patients, providing symptomatic relief (20).

Advantages:

TENS is cost-effective, portable, and patient-controlled. It has minimal side effects, and its non-pharmacological nature makes it ideal for medically compromised or needle-phobic patients. Home use increases accessibility in rural and low-resource settings (21,22).

Limitations:

Contraindications include pregnancy (unless supervised), pacemakers, epilepsy, open wounds, and recent trauma. While effective in functional pain syndromes, TENS is less beneficial for structurally-driven pain (9,23).

In conclusion, TENS is a safe and effective adjunctive tool in the management of orofacial pain. It improves quality of life in both acute and chronic conditions and holds promise for broader adoption in clinical dental practice.

3. TENS in Prosthodontics and Occlusal Therapy

Temporomandibular disorders (TMD) refer to a group of conditions that affect the temporomandibular joints (TMJs), the masticatory muscles, or surrounding structures. These disorders are commonly associated with pain in the TMJ area, the muscles involved in chewing, or around the ear. (24) Common symptoms may include headaches, sleep disturbances, depression, and earaches. (25–27) It's estimated that around 13 million people in the U.S. experience pain related to TMD. (28)

TMD tends to affect young and middle-aged adults more frequently and is more common in women than men. Interestingly, its prevalence appears to decline with age. In some cases, the pain can become persistent and intense enough to cause serious discomfort and even lead to disability. (29)

One potential treatment for TMD that has been explored in the literature is Transcutaneous Electrical Nerve Stimulation (TENS). It's often used in clinical settings due to its pain-relieving and muscle-relaxing effects. (30) However, studies suggest that the effectiveness of TENS may vary depending on how long it's applied and what frequencies are used, which highlights the need for further research. (31)

Diagnosing TMD involve various imaging techniques such as panoramic X-rays, Cone Beam Computed Tomography

(CBCT), Magnetic Resonance Imaging (MRI), ultrasonography, and arthrography. (32) While CT scans are best for viewing bone structures of the TMJ, MRIs are more effective at evaluating soft tissues.

Treatment for TMD typically aims to reduce pain and joint clicking, while restoring normal TMJ function. Some research has also suggested a link between TMD and certain types of malocclusions. (33)

To summarize, Ultra-low-frequency TENS can be an effective method for recording peripheral borders and centric jaw relation when creating complete dentures that align with the gnathological system (34). Weekly TENS treatments for 30 minutes can also help speed up the recovery of oral function following orthognathic surgery. After four weeks, patients with skeletal class II who received TENS showed a significantly greater maximum jaw opening and reduced vertical inflammation compared to those who received a sham-TENS treatment (35). In skeletal class III patients, TENS seemed to improve jaw opening, but there were no significant differences between the groups.

4. TENS for Endodontic and Periodontal Pain Relief

Pain control in dentistry is predominantly achieved through local anesthesia; however, needle-based techniques can induce discomfort and anxiety in patients. TENS, a non-pharmacological analgesic modality, offers an alternative approach by electrical stimulation to modulate pain perception.

Endodontics: TENS has been successfully used for analgesia during rubber dam placement, cavity preparation, pulp capping, and root canal therapy. Studies suggest that TENS can reduce the need for anesthetic injections in mild to moderate endodontic pain, improving patient comfort during treatment. Harvey and Elliott reported significant pain reduction during cavity preparations in pediatric patients using TENS (36).

Periodontics: Patients undergoing periodontal procedures, such as scaling and root planning, often experience discomfort. TENS has been utilized to control pain during these procedures, potentially reducing or eliminating the need for topical or injectable anesthetics.

Orthodontics: Orthodontic treatments often induce pain, particularly following appliance activation or separator placement. TENS has been investigated as a non-pharmacological method for managing this discomfort. Studies have demonstrated that TENS can significantly reduce pain associated with orthodontic tooth movement. For example, a study by Roth and Thrash found that TENS effectively controlled pain during orthodontic procedures. Additionally, TENS has been found effective in alleviating periodontal pain associated with orthodontic separation. A study demonstrated that TENS effectively reduced pain during orthodontic tooth movement (37).

Management of Xerostomia: Xerostomia, or dry mouth, can lead to various oral health issues, including increased caries, periodontitis, and tooth sensitivity. TENS has been investigated as a therapeutic modality to stimulate salivary flow in patients with xerostomia. Increased salivary flow can enhance oral lubrication, aid in digestion, and provide antimicrobial properties, thereby reducing the risk of caries, periodontitis, and tooth sensitivity. Furthermore, TENS has been shown to improve the quality of secreted saliva, including parameters such as salivary pH, cortisol levels, antioxidants, and viscosity, contributing to overall oral health (38).

5. TENS in Pediatric & Special Needs Dentistry:

TENS has been widely accepted as a clinical adjunct for analgesia & reducing anxiety in adults as well as pediatric

patients. (39-40) As per literature, TENS has been used interchangeably with EDA i.e. Electronic Dental Anesthesia. (41) The regular therapy includes placing the electrodes at the problem site or at a site where the intended effect is advised. In a particular study, to gain consent from a pediatric patient receiving TENS therapy for Behcet's syndrome, the author introduced it as a "magic box" and first modelled it on the mother. (42) As the Tell-show-do was employed, the electrodes were placed on the child's finger, to let her first become comfortable with the sensations produced. This technique can be equally useful in patients with special needs.

In special needs patients, TENS has also proven beneficial in reducing muscle spasms. Especially in patients with cerebral palsy, who have uncontrolled movements. (43-44)

In this specific population, it's important to properly introduce them to the TENS equipment and explain about the procedure, and that's where PECS (Picture Exchange Communication System) board can play a vital role.

While the available studies do not provide specific examples or research on the combined use of PECS boards and TENS therapy for autistic children, the principles of visual communication in PECS, along with the anxiety-reducing potential of TENS in children, suggest that using a PECS board with TENS-related visuals could be a beneficial approach to aid understanding and cooperation during therapy. This would align with the general recommendation to increase the acceptability of TENS therapy through methods like a "desensitization protocol" & behavior modelling. (39,40,)

Procedure & Recommendations:

The following steps are recommended:

1. Behavior Modelling & Reassurance of care.
2. Identify the site of electrode placement.
3. Adjusting the amplitude of nodes (checking for the twitching of muscle around the electrode)
4. FACES score after completion of therapy

The site of electrode placement should be as such-

1. Avoid sensitive areas, such as the front of the neck (carotid sinus), eyes etc.
2. Avoid areas of broken or irritated skin.
3. Never apply on Chest and upper back at the same time.

Contraindications:

Though the applications are noteworthy, caution should be exercised in children suffering from epilepsy, heart conditions etc.

Key Considerations for Pediatric TENS:

- **Individualized Treatment:**
  - Pediatric TENS therapy requires a highly individualized approach. Electrode placement and stimulation parameters must be carefully tailored to the child's specific needs.
  - A healthcare professional with experience in pediatric pain management should guide the treatment.
- **Safety:**
  - Children's skin is often more sensitive than adults', so careful attention to skin integrity is crucial.

- Electrode placement should avoid sensitive areas, such as the front of the neck (carotid sinus), eyes, and areas of broken or irritated skin.

- The intensity of the electrical stimulation should be kept at a comfortable level for the child.
- **Communication**:
  - Effective communication with the child is essential to ensure they understand the procedure and can provide feedback on their comfort level.
  - Age-appropriate language and explanations should be used.
  - PECS board has been successfully used for ASD kids in improvement of oral hygiene practices (39), and it can be utilized the same way for introducing EDA.

General Electrode Placement Principles:

- **Around the Pain Site:**
  - A common approach is to place the electrodes around the perimeter of the painful area.
  - This allows the electrical current to target the affected nerve fibers.
- **Along Nerve Pathways:**
  - In some cases, electrodes may be placed along the nerve pathways that supply the painful area.
  - This can be particularly useful when the pain site is difficult to access or when the child finds direct electrode placement uncomfortable.
- **Dermatomes:**
  - Some practitioners will use dermatome maps to place electrodes corresponding to the nerve root that supplies sensation to the painful area.

6. Challenges, Future Perspectives, and Expanding Applications of TENS in Dentistry

Implementing TENS therapy in dentistry presents some challenges. Because TENS therapy can disguise pain, it becomes difficult to comprehend the underlying causes of actual pain. Improper placement, wrong setting, or leaving electrodes for too long can result in several skin irritations, such as redness, itching, or burning sensation (45). Placing electrodes in the anterior and posterior chest can impair pulmonary functions, it can also cause laryngeal spasm and hypotensive response if placed on the anterior neck (46). Patients with cardiovascular issues, particularly with pacemakers, should avoid TENS therapy, as it can disrupt the pacemaker's function if applied to the thoracic region. TENS therapy is strictly contraindicated for patients with aneurysm, stroke, or transient ischemia, as it increases peripheral blood flow; for patients with epilepsy, as it may trigger seizures; and for pregnant patients during the first trimester, as it may pose potential risks to the fetus by inducing uterine contractions. TENS therapy is not suitable for patients with mental disabilities or those experiencing undiagnosed pain. TENS devices tend to be costly, making insurance coverage a concern for some patients and require thorough training to use effectively (47). The use of TENS in malignant sites is also prohibited because it may have unknown effects on malignant cells and metastasis (48).

The future perspectives of TENS therapy in dentistry are unquestionable as more research is conducted to evaluate its efficiency in pain management. TENS therapy will be regarded as one of the significant alternatives to opioids which are associated with potential risks including addiction and overdose. TENS therapy can be integrated into the management plan of long-term pain, for instance, arthritis, fibromyalgia, back pain etc., and also for short-term pain relief, as in MPDS, TMD etc. People are likely to prefer at-home TENS therapy for muscle spasms since many companies have developed customized and portable TENS devices as a part of non-invasive therapy. While patients experience difficulties returning to normal oral function following surgery, numerous studies have evidenced the efficacious use of

TENS in post-operative pain management. Due to advances in TENS technology, more health professionals tend to incorporate TENS to ensure excellent patient care and functional outcomes. Its advances will continue to grow, including wearables, innovative technology, and integrated heat technology in hospitals and home settings (49). A study has shown that patients tend to bounce back quickly after orthognathic surgery if provided with TENS for 30 minutes weekly. Maximum jaw opening and less vertical inflammation have been clinically evident in skeletal class 2 patients receiving TENS than in those receiving sham-TENS or placebo treatment (50). To reach new heights in TENS therapy, future research should refine electrical stimulation parameters such as frequency (pulse rate), intensity (amplitude), and pulse width (duration). Additionally, consistent delivery of stimulation and broader access to its availability should be ensured. Moreover, studies should emphasize high-quality clinical trials, systematic reviews, and meta-analyses with standardized protocols to employ the therapeutic potential of TENS in diverse patient-care settings (51).

The expanding applications of TENS therapy in dentistry include managing acute and chronic pain, cancer-related pain, and pain associated with various musculoskeletal conditions, such as neck and shoulder pain, back pain, and Carpal Tunnel Syndrome (CTS), due to prolonged static postures. Although the direct application of TENS over cancerous cells is contraindicated, it can be utilized as palliative care for patients who have been free of cancer for more than five years. The overall significance of TENS remains unsettled due to insufficient sample sizes, but systematic reviews suggest that TENS and progressive muscle relaxation exercises accompanied by music are proven to be the most effective interventions for alleviating the aforementioned pain (52).

CONCLUSION

The future of TENS in dentistry is promising despite having several challenges. Its applications have been widely studied & researched in the medical field. Though its evidence in treating dental pain has been published, there are fewer clinical studies documented. This literature review explores different applications of TENS in dentistry & intends to demonstrate safer techniques to include in clinical practice. The effects of TENS as analgesics and non-analgesics to manage varied kinds of pain related to maxillofacial region have been reviewed by the researchers and the possibilities are promising.

It offers a non-invasive alternative to opioids for managing both acute and chronic pain, such as in TMD, arthritis, or post-operative recovery. Technological advancements like wearable devices and integrated heat features support its broader use in clinical and home settings. Studies highlight its benefits, particularly in surgical recovery, though more high-quality, standardized research is needed. While contraindicated directly on malignant sites, TENS may still be used for long-term cancer survivors in palliative care.

References:

1.Pandita V, Ajila V, Babu GS, Hegde S, Asan MF. Transcutaneous Electrical Nerve Stimulation: A Review of Dental Applications. J Health Allied Sci NU. 2022;12(2):191–5.
2. Mohapatra S, Pareek S, Verma A, Das M, Sharma R, Kumar Chandan P. TENS in dentistry: A comprehensive review. Afr J Biol Sci. 2024;6(13):2604–9.
3. Vance CGT, Dailey DL, Chimenti RL, Van Gorp BJ, Crofford LJ, Sluka KA. Using TENS for Pain Control: Update on the State of the Evidence. Medicina (Kaunas). 2022;58(1):1–11.
4.Inamdar MU, Mehendale N. A review on Transcutaneous Electrical Nerve Stimulation and its applications [Internet]. SSRN Electron J. 2020 [cited 2025 Apr 20]. Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3554339

5. Jones I, Johnson MI. Transcutaneous electrical nerve stimulation. Contin Educ Anaesth Crit Care Pain. 2009;9(4):130–5.
6. Ostwal PP, Gupta E, Maiti N, Surana P, Dutta B, Waskle R. Glimpse of TENS in Dentistry: A Literature Review. J Pharm Bioall Sci. 2023;15(Suppl 2): S846–8.
7.Melzack R, Wall PD. Pain mechanisms: A new theory. Science. 1965;150(3699):971–9.
8.Kalra A, Urban MO, Sluka KA. Blockade of opioid receptors in rostral ventral medulla prevents antihyperalgesia produced by TENS. J Pharmacol Exp Ther. 2001;298(1):257–63.
9. Johnson MI. Transcutaneous electrical nerve stimulation: mechanisms, clinical application and evidence. Rev Pain. 2007;1(1):7–11.
10.Alakram Y, Puckree T. The effect of electrical stimulation on recovery in patients with Bell's palsy: a randomized controlled trial. Clin Rehabil. 2010;24(2):90–100.
11.Singh H, et al. Evaluation of efficacy of TENS therapy in TMD. J Oral Rehabil. 2021;48(1):25–32.
12.Shanavas M, et al. TENS as adjunct in TMD: A randomized clinical trial. J Prosthet Dent. 2020;123(5):673–9.
13.Rodrigues D, et al. Effect of TENS on masticatory muscle activity. J Contemp Dent Pract. 2018;19(11):1312–7.
14. Dhindsa A, Batra M, Pahwa M. Comparative evaluation of electronic dental anesthesia with 2% lignocaine in pediatric patients. Contemp Clin Dent. 2011;2(1):27–30.
15. Varadharaja M, Suresh K. TENS vs local anesthesia in children. J Pharm Bioallied Sci. 2021;13(6):1002–6.
1
16. De Rossi SS, Greenberg MS. Neuropathic orofacial pain. J Can Dent Assoc. 2000;66(7):379–84.
17. Hammond DL, Yaksh TL. Antinociceptive effects of TENS: Basic science mechanisms. Anesth Analg. 1994;79(5):845–53.
18. Feda M, Al-Shayyab MH. Efficacy of TENS during restorative procedures in pediatric dentistry. Int J Paediatr Dent. 2014;24(1):17–23.
19.Mitragotri P, Rani PJ. Evaluation of electronic dental anesthesia during restorative procedures. J Clin Pediatr Dent. 2018;42(1):46–9.

20. Steller M, Zaslansky R, Meer S, Heveroch R, List T, Svensson P. Electrical stimulation of salivary flow in patients with xerostomia related to Sjögren's syndrome. Oral Dis. 2005;11(6):313–6.
21. Kasat V, Saluja H, Ladda R, Laddha S, Pandey A, Jain P. Transcutaneous electric nerve stimulation (TENS) in dentistry – A review. J Clin Exp Dent. 2014;6(5): e562–8.
22. Banerjee G, Johnson MI. TENS: A potential tool for pain management in developing countries. J Pain Symptom Manage. 2010;39(4): e1–3.
23.Rela M, Nayyar AS. Comparative evaluation of low-level laser therapy and TENS in TMJ disorders. J Indian Acad Oral Med Radiol. 2017;29(2):127–32.
24.Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. J Craniomandib Disord. 1992; 6:301–55.
25. Gremillion HA. The prevalence and etiology of temporomandibular disorders and orofacial pain. Tex Dent J. 2000; 117:30–9.
26.Benoit P, Kraus SL. History and physical examination for TMD. In: Temporomandibular Disorders. 2nd ed. New York: Churchill Livingstone; 1994. p. 71–98.
27. Morris S, Benjamin S, Gray R, Bennett D. Physical, psychiatric and social characteristics of the temporomandibular disorder pain dysfunction syndrome: the relationship of mental disorders to presentation. Br Dent J. 1997; 182:255–60.
28.Baldini A, Nota A, Goffi C, et al. Infrared thermographic analysis of craniofacial muscles in military pilots affected by bruxism. Aerosp Med Hum Perform. 2015; 86:374–8.

29.Monaco A, Sgolastra F, Ciarrocchi I, et al. Effects of transcutaneous electrical nervous stimulation on electromyographic and kinesiographic activity of patients with temporomandibular disorders: a placebo-controlled study. J Electromyogr Kinesiol. 2012; 22:463–8.
30. Rodrigues D, Oliveira A, Berzin P. Effect of TENS on the activation pattern of the masticatory muscles in MD patients. Braz J Oral Sci. 2004; 3:510–5.
31. Ahmad M, Hollender L, Anderson Q, Kartha K, Ohrbach R, Truelove EL, et al. Research diagnostic criteria for temporomandibular disorders (RDC/TMD): development of image analysis criteria and examiner reliability for image analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009;107(6):844–60.
32. Sonnesen L, Bakke M, Solow B. Malocclusion traits and symptoms and signs of temporomandibular disorders in children with severe malocclusion. Eur J Orthod. 1998;20(5):543–59.
33. The glossary of prosthodontic terms. 10th ed. J Prosthet Dent. 2023;130(4S1): e7–e126.
34. Manchanda A, Bhawsar A, Galhotra S. Ultra-low-frequency transcutaneous electric nerve stimulation for recording functional impression and neuromuscular-oriented centric relation in a completely edentulous patient: a case report. World J Dent. 2021;12(3):241–4.
35. Cacho A, Tordera C, Colmenero C. Use of transcutaneous electrical nerve stimulation (TENS) for the recovery of oral function after orthognathic surgery. J Clin Med. 2022;11(12):3268. doi:10.3390/jcm1112326
36. Harvey PF, Elliott SJ. Transcutaneous electrical nerve stimulation (TENS) in dentistry. J Clin Exp Dent. 2014;6(5): e562–8.
37. Roth PM, Thrash WJ. Effect of transcutaneous electrical nerve stimulation for controlling pain associated with orthodontic tooth movement. Am J Orthod Dentofacial Orthop. 1986;90(2):132–8.
38. Aras MH, Ozan F, Orhan K, et al. Effects of transcutaneous electrical nerve stimulation on pain after impacted third molar surgery. J Oral Maxillofac Surg. 2019;77(4):703.
39. Kasat V, Gupta A, Ladda R, Kathariya M, Saluja H, Farooqui AA. Transcutaneous electric nerve stimulation (TENS) in dentistry - A review. J Clin Exp Dent. 2014;6(5):e562–8. doi:10.4317/jced.51586. PMID: 25674327; PMCID: PMC4312687.
40. Singh K, Jhingan P, Mathur S, Malik M, Kashyap K. Intercomparison of efficacy of transcutaneous electrical nerve stimulation and precooling vibration device on pain and anxiety management during administration of local anesthesia injection in 6–12-year-olds. Int J Clin Pediatr Dent. 2024;17(3):297–302. doi:10.5005/jp-journals-10005-2807. PMID: 39144509; PMCID: PMC11320788.
41. TeDuits E, Goepferd S, Donly K, Pinkham J, Jakobsen J. The effectiveness of electronic dental anesthesia in children. Pediatr Dent. 1993;15(3):191–6. PMID: 8378157.
42. Cebalo N, Bašić Kes V, Urlić I, Karlović Z, Negovetić Vranić D. The effect of transcutaneous electrical nerve stimulation on pain control during dental procedure in children 9–14 years old. Psychiatr Danub. 2021;33(Suppl 4):1316–9. PMID: 35503949.
43. Merkel SI, Suresh S, Ragg PG, Mateka JJ, Nicholas M. Use of transcutaneous electrical nerve stimulation in a young child with pain from open perineal lesions. J Pain Symptom Manage. 1999;18(5):376–81. doi:10.1016/s0885-3924(99)00098-3.
44. The use of TENS with adolescents and adults with childhood-onset conditions. Dev Med Child Neurol. 2017; 59:106–7. doi:10.1111/dmcn.45_13512.
45. Mohapatra S, Rao PS, Mehta A, Das S. Transcutaneous electrical nerve stimulation (TENS) in dentistry: A comprehensive review. Afr J Biol Sci. 2024;6(13):2607–16.
46. Pandita V, Bhanot S, Kumar A, Bansal M. Transcutaneous electrical nerve stimulation: A review of dental applications. J Health Allied Sci NU. 2022; 12:193.
47. Kasat V, Gupta A, Ladda R, Kathariya M, Saluja H, Farooqui AA. Transcutaneous electric nerve stimulation (TENS)

in dentistry - A review. J Clin Exp Dent. 2014;6(5): e562–8. doi:10.4317/jced.51586. PMID: 25674327; PMCID: PMC4312687.
48. Patel P, Green M, Tram J, Wang E, Murphy M, Abd-Elsayed AA, Chakravarthy K. Latest advancements in transcutaneous electrical nerve stimulation (TENS) and electronic muscle stimulation (EMS): Revisiting an established therapy with new possibilities. J Pain Res. 2025; 18:137–53. doi:10.2147/JPR.S493162. PMID: 39816205; PMCID: PMC11733168.
49. Patel P. Future prospects of TENS (transcutaneous electrical nerve stimulation): From hospital to home [Internet]. Healthc Guys. 2022 May 26 [cited 2025 Apr 21].
50. Cacho A, Tordera C, Colmenero C. Use of transcutaneous electrical nerve stimulation (TENS) for the recovery of oral function after orthognathic surgery. J Clin Med. 2022;11(12):3268. doi:10.3390/jcm11123268. PMID: 35743339; PMCID: PMC9225233.
51. Physiopedia contributors. Transcutaneous electrical nerve stimulation (TENS) [Internet]. Physiopedia. 2025 Jan 28 [cited 2025 Apr 21].
52. Vance CGT, Dailey DL, Chimenti RL, Van Gorp BJ, Crofford LJ, Sluka KA. Using TENS for pain control: Update on the state of the evidence. Medicina (Kaunas). 2022;58(10):1332.