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Sonic and Ultrasonic Devices and Instruments in Endodontics: Mechanisms, Clinical Applications, and Recent Advances

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Abstract

Background: The integration of sonic and ultrasonic technologies into endodontics has revolutionized the field, enhancing canal debridement, irrigant penetration, and precision during treatment. The synergistic use of acoustic energy and fluid dynamics allows improved cleaning efficacy, particularly in complex root canal anatomies where mechanical instrumentation alone is inadequate. This review article deals with the recent advances enabled in ultrasonic technology in the mainstream of endodontics in the last two to three decades in various steps of root canal therapy, such as activation of activation of irrigating solutions; finding calcified canals and removal of attached pulp stones; removal of intracanal obstructions (separated instruments, root canal posts, silver points, and fractured metallic posts); and ultrasonic condensation of gutta percha; in the field of surgical endodontics, it is also used for root-end cavity preparation and placement of root-end obturation material. The review aims to assess the success rates, compare outcomes, explore benefits and drawbacks of ultrasonics in endodontics.

Review: Sonic and ultrasonic activation utilize acoustic energy to enhance irrigant effectiveness through cavitation, acoustic microstreaming, and hydrodynamic shear. Ultrasonic systems (25–40 kHz) typically deliver higher energy and more effective cleaning than sonic systems (1–6 kHz), though newer flexible polymer-based sonic systems such as EDDY and EndoActivator have narrowed the gap in clinical efficacy. Applications include irrigant activation, post and instrument retrieval, access refinement, root-end preparation, and restorative finishing. Current research supports the superiority of passive ultrasonic irrigation in smear layer removal and microbial reduction, while emerging multisonic and piezoelectric systems (e.g., GentleWave, PiezoMaster 700) show promising outcomes with minimal dentin loss. This article presents a narrative review synthesizing current literature on sonic and ultrasonic devices in endodontics, focusing on their mechanisms, clinical applications, and emerging technological advances.

Conclusion: Sonic and ultrasonic activation are indispensable adjuncts to modern endodontic practice. Future integration of AI-assisted modulation, adaptive frequency control, and digital navigation will further enhance precision and predictability in canal cleaning and disinfection.

Keywords: Sonic irrigation, Ultrasonic activation, Endosonics, Acoustic microstreaming, Root canal disinfection, Piezoelectric endodontics, EDDY system

Introduction

Complete removal of tissue debris, bacteria, and biofilms from the intricate root canal system is central to the success of endodontic therapy. Mechanical instrumentation shapes the canal but fails to debride isthmuses, fins, and lateral canals. Irrigation thus becomes vital, yet conventional syringe irrigation is limited by hydrodynamic stagnation and apical vapor lock (Haapasalo & Shen, 2020).

The concept of energy-assisted irrigation—using sonic and ultrasonic devices—emerged to overcome these limitations. These devices deliver acoustic energy to the irrigant, generating streaming and cavitation effects that enhance cleaning without additional dentin removal (van der Sluis et al., 2016). The use of ultrasound in dentistry, originally restricted to scaling and cavity preparation, has evolved into a refined field of endosonics, integrating microscopic precision, digital control, and bioceramic synergy.

The present work represents a narrative review aimed at critically summarizing published data from the past four decades regarding the evolution, mechanisms of action, and clinical performance of sonic and ultrasonic technologies in endodontics.

Literature Selection: A non-systematic literature search was conducted in PubMed, Scopus, and Google Scholar databases using combinations of keywords such as "sonic irrigation," "ultrasonic activation," "endosonics," "piezoelectric endodontics," "root canal disinfection," and "acoustic microstreaming." Articles published in English from 1980 to 2025 were screened. Relevant original research papers, clinical trials, and review articles were included based on their contribution to understanding mechanisms, clinical applications, and recent technological advances of sonic and ultrasonic systems in endodontics.

Historical Background

The origins of ultrasound date back to Pierre and Jacques Curie (1880), who discovered the piezoelectric effect—the generation of electric potential by mechanical stress in crystalline materials. The first dental use of ultrasound occurred in the 1950s when Catuna (1953) introduced ultrasonic drilling for cavity preparation. However, it was Richman (1957) who pioneered the use of ultrasound for root canal cleaning, followed by Martin and Cunningham (1976), who developed the Cavitron Endosonic device, coining the term endosonics.

By the late 1990s, the introduction of diamond-coated retrotips and piezoelectric units revolutionized surgical endodontics. The 21st century saw the transition from magnetostrictive to piezoelectric systems, offering linear oscillation, reduced heat generation, and enhanced control. Concurrently, sonic systems like the EndoActivator and Vibringe introduced air-driven acoustic energy at lower frequencies with flexible polymer tips to ensure safety in curved canals (Plotino et al., 2022).

Physical Principles and Mechanisms

The clinical effectiveness of sonic and ultrasonic devices arises from three key physical phenomena: acoustic microstreaming, cavitation, and hydrodynamic shear stress.

1. Cavitation

Cavitation refers to the formation, growth, and implosion of microbubbles in a liquid medium exposed to alternating pressure waves. These implosions generate localized shock waves and high-velocity microjets capable of dislodging debris and disrupting bacterial biofilms (Căpută et al., 2019). Transient cavitation, which occurs at higher amplitudes (>25 kHz), is predominant in ultrasonics. Stable cavitation, producing gentle oscillation of bubbles, is more common in sonic systems.

2. Acoustic Microstreaming

This is the continuous, rapid, vortex-like movement of fluid around an oscillating file or tip. Microstreaming induces strong shear forces that detach smear layer, necrotic tissue, and bacteria from canal walls (Ahmad et al., 1987). Shear stress peaks near the tip and antinodes of the vibrating file, particularly when the instrument is unconstrained within the canal (Walmsley et al., 2011).

3. Hydrodynamic Agitation and Heat

Oscillating files produce fluid turbulence, increasing irrigant exchange and penetration. The mild frictional heating that occurs enhances NaOCl reactivity but must be controlled to prevent dentin dehydration. Piezoelectric units are preferred for their linear vibration and minimal thermal output.

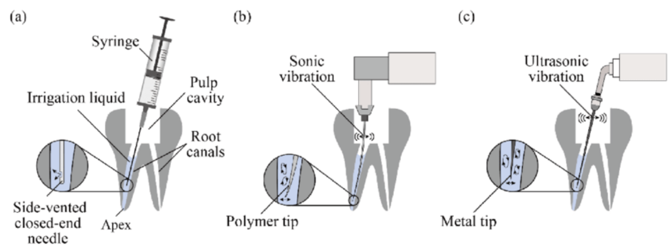

Figure 1: Schematic illustration of different irrigation techniques:

(a) conventional syringe irrigation, (b) passive sonic irrigation using a polymer tip, and (c) passive ultrasonic irrigation using a metal tip. Sonic and ultrasonic activation enhance irrigant movement through cavitation and acoustic microstreaming, improving debris removal and disinfection compared to syringe irrigation.

Classification of Sonic and Ultrasonic Devices

Category	Sonic Systems	Ultrasonic Systems
Operating Frequency	1–6 kHz	25–40 kHz
Energy Source	Air-driven handpiece	Magnetostrictive / Piezoelectric transducer
Tip Material	Flexible polymer or NiTi	Stainless steel, Ti alloy, diamond-coated
Motion Pattern	Elliptical	Linear (piezoelectric) / Elliptical (magnetostrictive)
Examples	EndoActivator, EDDY, Vibringe	ProUltra, BUC, CPR, KiS, BL tips
Cavitation Potential	Low	High
Heat Generation	Minimal	Moderate (requires irrigation)

Category	Sonic Systems	Ultrasonic Systems
Application Focus	Irrigant activation, gentle debridement	Precise cutting, post/instrument retrieval, microsurgery

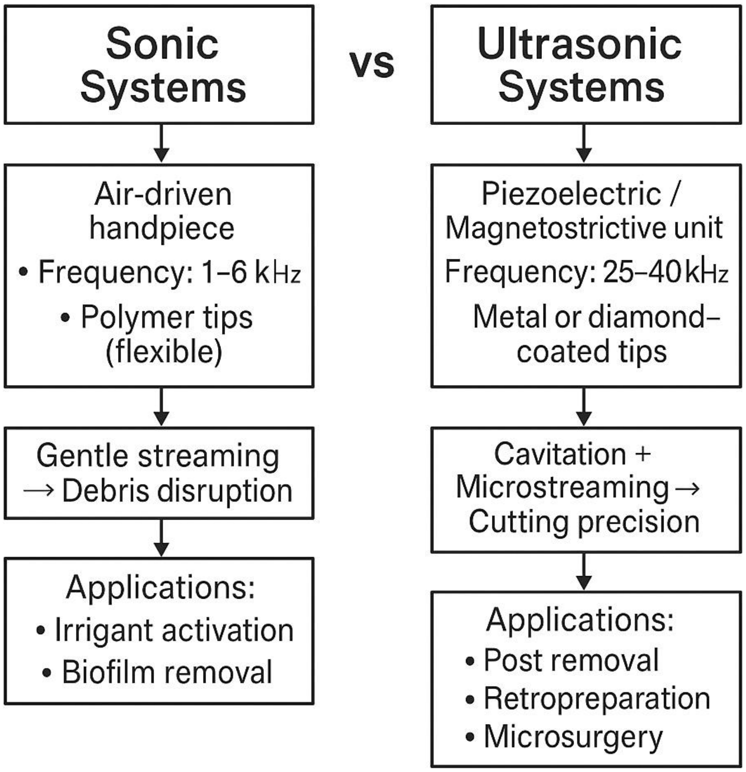

Figure 2: Flowchart comparing sonic and ultrasonic systems in endodontics

Sonic Devices in Endodontics

EndoActivator (Dentsply Sirona)

Introduced in 2007, this cordless device operates at 2–3 kHz using flexible polymer tips of 15–35 sizes. It effectively disrupts biofilms and removes debris from lateral canals while minimizing apical extrusion (De Gregorio et al., 2010).

Vibringe System

Combines manual syringe irrigation with sonic vibration at 5 kHz. Though less effective than PUI, it enhances irrigant replacement and is easy to integrate in routine practice.

EDDY (VDW, Germany)

A newer sonic device utilizing a polyamide tip vibrating at 6 kHz. Studies by Pereira et al. (2023) and Urban et al. (2024) demonstrated that EDDY achieves debris removal comparable to ultrasonics while preserving dentin integrity and avoiding tip wear.

Ultrasonic Devices in Endodontics

Types of Systems

1. **Magnetostrictive:** Converts magnetic energy to mechanical motion via metal stack elongation (e.g., older Cavitron systems).
2. **Piezoelectric:** Uses ceramic crystals to generate linear vibrations—preferred for precision and

reduced heat (e.g., ProUltra, EMS Piezon Master 700).

Common Tips and Applications

- **CPR & BUC Tips:** For troughing, access refinement, and post removal.
- **ProUltra Endo & SINE Tips:** Zirconium nitride or diamond-coated; ideal for pulp stone removal and fine dissection.
- **KiS and BL Microsurgical Tips:** For retropreparation under DOM, ensuring smooth cavity margins and minimal bevel.

Clinical Applications

1. Irrigant Activation

Passive Ultrasonic Irrigation (PUI) has been shown to significantly enhance the elimination of debris and smear layer compared to syringe irrigation (van der Sluis et al., 2016; Haapasalo et al., 2020). Căpută et al. (2019) and Boutsioukis et al. (2023) found superior apical cleaning and bacterial reduction when NaOCl was ultrasonically activated for ≥20 s cycles.

2. Detection and Negotiation of Calcified Canals

Ultrasonic tips (e.g., CPR, BUC series) allow conservative dentin removal and identification of hidden canals, particularly MB2 in maxillary molars (Ruddle, 2022).

3. Removal of Posts and Separated Instruments

Ultrasonic vibration along the length of metallic posts weakens cement bonds, allowing non-invasive retrieval (Plotino et al., 2022). Controlled activation under the microscope minimizes perforation risk.

4. Access Refinement and Cavity Preparation

Micro-ultrasonics permit precise dentin brushing and cavity shaping. Under DOM, operators can selectively remove calcified dentin while maintaining pericervical structure integrity (Ruddle, 2020).

5. Surgical Root-End Procedures

Piezoelectric microsurgical tips (KiS, BL) enable accurate retrocavity preparation with smooth margins and optimal depth, producing minimal bevels and preventing crack propagation (Peters et al., 2021).

6. Restorative Dentistry

Ultrasonic systems refine cavity walls, remove defective restorations, and facilitate margin finishing with less vibration and noise compared to rotary instruments.

Advantages

- Enhanced cleaning efficacy and irrigant exchange
- Superior access and visibility under DOM
- Minimal dentin removal and structural preservation
- Improved microbial reduction and sealer adaptation
- Reduced iatrogenic errors
- Versatility for both surgical and nonsurgical uses

Limitations

- Technique sensitive and operator dependent
- Possible heat generation or root surface damage
- File fracture risk under constrained conditions
- Reduced cavitation in narrow canals
- Equipment cost and maintenance

Recent Developments (2020–2025)

1. **EDDY and Polymer Sonic Tips (2023–2025):** Polyamide tips at 6 kHz produce high-amplitude oscillations, inducing vigorous streaming with minimal dentin stress (Pereira et al., 2023).
2. **GentleWave Multisonic System (Sonendo):** Uses broad-spectrum acoustic energy and negative pressure for irrigant circulation. Clinical studies show 99.6% biofilm reduction and superior healing rates (Haapasalo et al., 2024).
3. **XP-Endo Finisher & Finisher R:** NiTi adaptive files that agitate irrigant without dentin cutting—complementary to PUI.

4. **Piezoelectric Ultrasonics with AI Feedback:** Next-gen piezo devices (e.g., Piezon Master 700, PiezoWave) incorporate feedback loops to auto-adjust frequency and prevent overheating.
5. **Integration with Digital Navigation:** CBCT-guided ultrasonic navigation aids in selective dentin removal and microsurgical accuracy (Shen & Haapasalo, 2024).

Evidence Synthesis

Recent comparative studies show:

- **Ultrasonics > Sonic > Syringe** in smear layer removal (De Deus et al., 2023; Donnermeyer et al., 2020).
- **EDDY ≈ Ultrasonic** in debris removal (Pereira et al., 2023).
- **Gentle Wave > PUI** in biofilm eradication (Haapasalo et al., 2024).
- **Clinical outcome RCTs** (2021–2024) report marginally better periapical healing with activated irrigation compared to syringe irrigation, though differences are not always statistically significant.

Table 1: Summary of validated literature comparing clinical and experimental outcomes of sonic and ultrasonic irrigation systems in endodontics

Study (Year)	Device/System	Key Findings	Clinical Outcome
Căpută et al., 2019	Ultrasonic (Passive Ultrasonic Irrigation – PUI)	Systematic review demonstrated superior debris and smear-layer removal compared with syringe irrigation.	Significantly improved canal cleanliness and disinfection.
Chu et al., 2023	Sonic (EDDY) vs Ultrasonic	Meta-analysis revealed comparable cleaning efficiency between sonic (EDDY) and ultrasonic activation, with slightly reduced dentin wear for sonic devices.	Similar cleaning efficacy; sonic safer for curved canals.
Paixão et al., 2024	Ultrasonic vs Sonic	Experimental study comparing extrusion risk, debridement, and biofilm removal showed both systems effective; ultrasonic activation provided marginally superior results in larger apical sizes.	Enhanced debris removal and disinfection; caution for extrusion in larger apical sizes.
Silva et al., 2021	Piezoelectric Ultrasonic Systems	Review summarized advances in irrigant delivery and highlighted improved control, efficiency, and cutting precision using piezoelectric ultrasonics.	Greater surgical accuracy and minimally invasive preparation.
Deleu et al.,	Ultrasonic (PUI)	Systematic review and meta-analysis	Improved periapical healing and

Study (Year)	Device/System	Key Findings	Clinical Outcome
2024		indicated higher periapical healing rates following ultrasonic activation compared with conventional irrigation.	treatment success.

Future Perspectives

Next-generation endodontic ultrasonics will focus on controlled energy modulation, AI-driven irrigation dynamics, and minimally invasive canal shaping. Integration with bioceramic sealers and digital workflow systems will promote superior obturation and sealing. Hybrid sonic–ultrasonic systems and laser–ultrasound synergies are under active investigation to optimize 3D canal disinfection.

Conclusion

Sonic and ultrasonic technologies have become integral to contemporary endodontics. Their ability to enhance irrigant dynamics, conserve tooth structure, and improve procedural precision underscores their clinical importance. While ultrasonic systems remain the gold standard for high-energy activation, modern sonic devices like EDDY offer safe, efficient, and cost-effective alternatives.

With continued innovation in piezoelectric materials, adaptive frequency control, and digital integration, the future of endosonics promises greater efficiency, predictability, and minimally invasive excellence.

References

1. Ahmad M, Pitt Ford TR, Crum LA. Ultrasonic debridement of root canals: acoustic streaming and its possible role. J Endod. 1987;13(10):490–499. https://pubmed.ncbi.nlm.nih.gov/3482226/
2. van der Sluis LWM, Versluis M, Wu MK, Wesselink PR. Passive ultrasonic irrigation of the root canal: a review. Int Endod J. 2007;40(6):415–426.https://pubmed.ncbi.nlm.nih.gov/17442017/
3. Plotino G, Pameijer CH, Grande NM, Somma F. Ultrasonics in endodontics: a review. *J* Endod. 2007;33(2):81–95. https://pubmed.ncbi.nlm.nih.gov/ 17258622/
4. Mozo S, Llena C, Forner L. Review of ultrasonic irrigation in endodontics. Med Oral Patol Oral Cir Bucal.2012;17(3):e512–e516 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3476090/
5. Căpută PE, Retsas A, Kuijk L, Boutsioukis C. Ultrasonic irrigant activation during root canal treatment: a systematic review. *J Endod.* 2019; 45 (1):31–44. https:// pubmed.ncbi.nlm.nih.gov/ 30558797/
6. Virdee SS, Farnell DJJ, Silva MA, Camilleri J, Cooper PR, Tomson PL. The influence of irrigant activation, concentration and contact time on sodium hypochlorite penetration into root dentine: an ex vivo experiment. Int Endod *J*.2020 Jul;53(7):986–997. doi:10.1111/ iej.13290. PMID: 32163598. https://pubmed.ncbi.nlm.nih.gov/32163598/ · https://doi.org/10.1111/iej.13290
7. Gomes BPFA, et al. Irrigants and irrigation activation systems in Endodontics. Int J Dent. 2023. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10642269/
8. Paixão S, Gomes P.S., Fernandes M.H., Rodrigues C., Grenho L. Comparative Evaluation of Ultrasonic and Sonic Irrigant Activation Systems: Assessing

Extrusion Risk, Debridement, and Biofilm Removal in Distinct Apical Preparation Sizes. *Appl Sci*. 2024;14:3904.doi:10.3390/app14093904. https://doi.org/10.3390/app14093904 \

9. Ruddle CJ. Ultrasonics in endodontics: the state of the art. Dent Today. 2022;41 (6):100–105. https://www.dentistrytoday.com/category/endodontics/
10. Ruddle CJ. Endodontic disassembly: ultrasonic applications. Dent Today. 2024;43 (3):95–102. https://www. dentistrytoday.com/