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Sweeps technology in endodontics

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Abstract
Laser-activated irrigation of dental root canals has gained popularity recently due to its improved antibacterial effect and its ability to effectively irrigate complex root canal morphology compared to traditional methods.
SWEEPS -Shock Wave Enhanced Emission Photoacoustic Streaming is an attempt to improve the efficacy of laser assisted endodontic procedures for disinfecting and activating the complex root canal system. This modality enablesthe creation of primary and secondary shock waves. SWEEPS is based on the transmission of shorter double pulses. Owing to the shorter pulse duration, the peak power of each SWEEPS pulse is doubled at the same energy, resulting in a stronger bubble explosion and implosion unlike PIPS mode with single pulse energy emission. Emission of a couple of consecutive laser pulses, with the second subsequent laser pulse that shoots into the liquid at an optimal delay time from the first pulse, when the initial bubble is in the final phase of its collapse. This phenomenon produces an acceleration of the laser- induced bubbles collapse, leading to the emission of shock waves also in narrowroot canals.
SWEEPS have superior chemical activation of NaOCl, superior chemicaldissolving of pulp, superior physical disrupting impact on biofilm, better smear layer cleaning capacity than EDTA and superior bactericidal impact.

Keywords: Laser-activated irrigation of dental root canals has gained popularity recently due

Introduction
Effective root canal disinfection is essential for the long-term success of endodontic treatment. Mechanical instrumentation alone is insufficient to clean the complex anatomy of the root canal system, which often includes isthmuses, fins, lateral canals, and dentinal tubules. Studies have shown that traditional instrumentation may only contact 60–70% of canal walls, leaving significant areas untouched where bacteria and biofilms can persist [1]. This limitation has driven the need for advanced irrigation techniques to complement mechanical debridement.
Conventional syringe-and-needle irrigation lacks the ability to effectively deliver irrigants into the apical third and intricate canal spaces. To address this, technologies such as sonic and ultrasonic activation, apical negative pressure systems, and laser-activated irrigation have been developed. These methods enhance irrigant penetration, fluid dynamics, and the disruption of microbial biofilms [2, 3]. Furthermore, innovations like multisonic and photoacoustic irrigation have demonstrated improved cleaning efficacy, especially in minimally prepared canals [4].
Laser-activated irrigation (LAI) involves the activation of endodontic irrigants using lasers with specific wavelengths. Among the most commonly used are erbium lasers, such as erbium chromium: yttrium-scandium-gallium-garnet (Er, Cr: YSGG) at 2780 nm, and erbium: yttrium-aluminum-garnet (Er:YAG) at 2940 nm. These wavelengths are highly absorbed in water and operate by generating **cavitation** in the irrigating solution, thereby enhancing cleaning efficacy through the creation of vapor bubbles and shock waves that disrupt debris and biofilm [5, 6] A recent advancement in this field is the Shock Wave Enhanced Emission Photoacoustic Streaming (SWEEPS)technology. This technique builds upon the Photon-Induced Photoacoustic Streaming (PIPS) method, wherein a pulsed Er: YAG laser is used to activate irrigants. In the SWEEPS approach, a laser fiber tip is positioned in the pulp chamber filled with an irrigant, and paired laser pulses are emitted into the fluid. This dual-pulse system generates overlapping shock waves that interact to produce enhanced pressure dynamics, surpassing the effectiveness of single-pulse systems like conventional PIPS [7, 8]. The resulting amplified fluid motion improves the removal of debris and microorganisms from the complex anatomy of the root canal system.
Thus, the advancement of irrigation techniques in endodontics is a response to the anatomical complexity of the root canal system and the biological demand for thorough disinfection and critical for reducing treatment failures and improving patient outcomes.

Sweeps Technology
Shock Wave Enhanced Emission Photoacoustic Streaming (SWEEPS) represents a significant advancement of the Photon-Induced Photoacoustic Streaming (PIPS) technique. Both techniques utilize the Er: YAG laser (2940 nm), which is strongly absorbed in water and is highly effective in generating intracanal cavitation and pressure waves to aid in root canal disinfection. SWEEPS enhance this mechanism by delivering paired laser pulses in rapid succession, thereby inducing overlapping shock waves within the irrigant-filled pulp chamber. This dual-pulse modality increases pressure amplitude and fluid dynamics more effectively than the single-pulse mechanism of traditional PIPS [9].

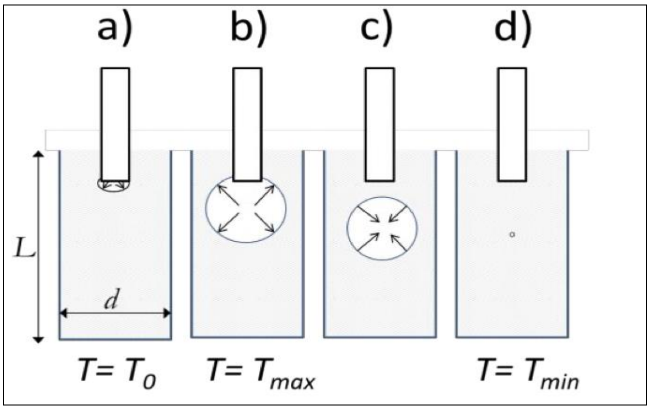
Currently, SWEEPS technology is available through two main laser platforms developed by **Fotona**: the LightWalker®and SkyPulse® systems.

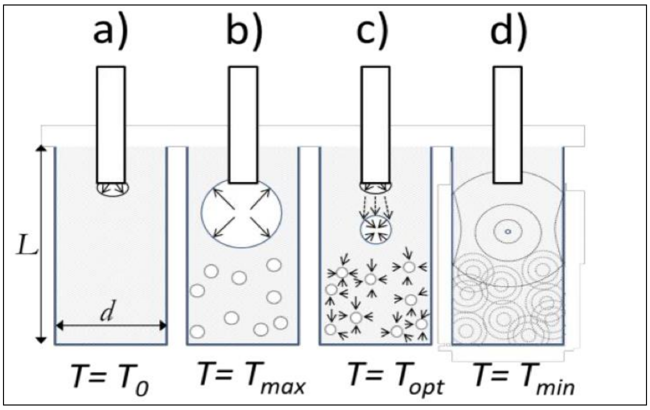
- **LightWalker®** is a dual-wavelength system incorporating both Er: YAG and Nd: YAG lasers. It enables TwinLight® endodontic and periodontal treatments and features built-in scanner-ready technology, making it a unique and ergonomic choice for dental practitioners.

- **SkyPulse®** is a newer, compact, and portable laser platform with a highly customizable user interface. It offers user-friendly operation with selectable presets or manual control of treatment parameters, making advanced laser dentistry accessible to a broader range of clinical practices.

In endodontic mode, both systems support energy emission in two primary pulse modalities:

1. **Single Pulse Mode**
2. **Dual Pulse Mode**





Single-Pulse SSP Laser-Assisted Irrigation

The SSP (Super Short Pulse) mode emits laser pulses of 50 μs duration, allowing for rapid energy absorption in the irrigant (typically a ~1 mm thick fluid layer). This results in instantaneous vapor bubble formation at the fiber tip (FT) immersed in the irrigant. The laser energy heats the fluid locally beyond its boiling point, producing a rapidly expanding vapor bubble that subsequently collapses under surrounding pressure, generating turbulent fluid movement within the root canal system. This phenomenon enhances chemo-mechanical debridement by improving the flow and distribution of irrigants.

Importantly, the use of ultra-short pulses minimizes thermal diffusion during bubble lifetime, preserving the opto-dynamic efficiency of bubble formation. Longer pulses allow heat to dissipate, reducing the energy available for cavitation [10]

USP (Ultra Short Pulse): Enables either increased modulation of energy with the same peak power (e.g., 400 W using only 10 mJ) or enhanced peak power (up to 800 W) using 20 mJ—equivalent to PIPS energy levels but with greater clinical flexibility.

Dual-Pulse SWEEPS® Laser-Assisted Irrigation

Building upon SSP, the SWEEPS® modality introduces a second laser pulse at a precise time delay following the first. This dual-pulse approach aims to overcome the limitation that shock waves are dampened in narrow spaces like root canals due to friction against canal walls and restricted fluid movement.

The second laser pulse is delivered at the optimal time (T_{opt})—typically during the collapse phase of the primary bubble. The interaction of the second bubble with the first collapsing bubble accelerates bubble implosion and enhances the generation of primary and secondary shock waves, improving irrigant agitation and biofilm disruption [6].

X-SWEEPS®: Fixed-Time Dual Pulse Emission

The X-SWEEPS® modality allows for a fixed time interval (T_p) between two laser pulses. The highest irrigation efficiency is observed when T_p closely matches T_{opt} (i.e., during the late collapse phase of the first bubble). This resonant timing maximizes pressure wave amplitude and promotes effective irrigant streaming.

Interestingly, studies show that T_{opt} can be estimated based on access cavity shape, size, pulse energy, and fiber-tip characteristics, making this modality predictable and customizable for molars, premolars, and incisors [6].

AutoSWEEPS®: Dynamic Pulse Timing

To simplify implementation, AutoSWEEPS® was developed to dynamically vary the inter-pulse delay between 200–650 μs, sweeping through a range that always includes T_{opt}. This ensures optimal conditions are approximated along the entire depth and width of the canal system, regardless of individual tooth anatomy.

In *vitro* studies show that AutoSWEEPS is:

- ~50% more effective than SSP in generating intracanal pressure
- Provides ~3× better debris clearance than SSP
- Outperforms ultrasonically activated irrigation (UAI) and SSP in debris removal across all regions of the root canal system [11,12]

Clinical Advantages of SSP/SWEEPS® Technology

According to Jezeršek *et al.*, both AutoSWEEPS and X-SWEEPS significantly outperform SSP in debris removal efficiency [11]. These laser-assisted modalities provide the following benefits:

- Enhanced irrigant penetration into dentinal tubules
- Greater efficacy in narrow or anatomically complex canals
- Reduced thermal risk due to ultra-short pulse durations
- Simplified clinical workflow while maintaining high safety margins

Ultimately, SSP/SWEEPS® technology aligns with the core goals of endodontic irrigation: optimal cleaning, disinfection, and conservation of tooth structure [19].

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