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EDITORIAL

Beyond the Hype: What Is the True Value of Advanced Disinfection Technologies in Endodontics?

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Despite the long-term success rate of root canal treatment for teeth with apical periodontitis exceeding 80% (1), many patients still experience tooth loss following the procedure. The primary reason for failed root canal treatment is the presence of intra-radicular bio-film, which poses a significant challenge due to the complexities of root canal anatomy (2,3). Research has focused on improving disinfection strategies to enhance the effectiveness of cleaning these complex anatomies without compromising tooth structure. This has led to a stronger emphasis on the delivery of irrigants within the root canal system. Over the past decade, several innovative strategies have emerged to improve the efficiency of root canal disinfection. However, the cost of implementing these technologies in a dental practice can range from $70,000 to $100,000. While modernizing clinical practice is important, endodontists must evaluate whether advanced disinfection technologies genuinely enhance the outcomes and efficacy of endodontic treatment.

The use of laser systems in dentistry has been established for decades, and their application has gained significant attention in endodontics, particularly for enhancing irrigation activation. Medium infrared wavelengths, including Er:YAG (2940 nm, e.g. Fotona®) and Er,Cr:YSGG (2790 nm, e.g. Biolase®, EdgePRO®), have been incorporated into recent laser-assisted irrigation devices and systems. The Er:YAG laser is preferred due to its better absorption coefficient in water and its ability to vary pulse duration, which allows for more consistent energy absorption. As a result, it requires less energy and time to ablate tissue, thereby reducing the risk of ledging or thermal damage to the root canal dentin commonly associated with the Er,Cr:YSGG laser (4,5). In practice, the fiber tip of the Er:YAG laser can be placed within the pulp chamber with a constant flow of irrigant. The high-power peaks generated create pressure waves through the expansion and collapse of vapor bubbles at the site of laser irradiation. Additionally, numerous secondary cavitation bubbles form after the collapse of the vapor bubble, occurring at a notable distance from the fiber tip.

Published studies indicate that laser-assisted irrigation (LAI) is more effective than conventional irrigation and shows a trend of greater efficacy compared to passive ultrasonic irrigation (PUI) in eliminating micro-organisms, dentin debris, and smear layer from the root canal system (6,7). Unpublished data presented at the American Association of Endodontists (AAE) Annual Meeting in 2025 suggests that the photon-induced photoacoustic streaming (PIPS) technique may be more effective than the GentleWave system for hard-tissue removal. However, the GentleWave system has been shown to remove remaining pulp tissue in the root canal system more effectively than PIPS, as indicated by histological slides. It is important to note that the anti-bacterial effectiveness of these advanced techniques primarily depends on the anti-bacterial properties of sodium hypochlorite and the volume of irrigant used. For example, when SWEEP technology was used with saline, it did not demonstrate effective anti-bacterial efficacy (8).

The GentleWave system, a multi-sonic device, generates a powerful, high-speed shear force that dispenses irrigants into the root canal system without needing to place the handpiece tip directly into the canal orifice. To optimize energy supply and eliminate the vapor-lock effect, the irrigants undergo a degassing process to remove dissolved gas from the solution. When the solution flows from the handpiece into stagnant fluid in the pulp chamber, hydro-dynamic cavitation occurs, triggered by shear forces that form thousands of microbubbles known as cavitation clouds. The implosion of these micro-bubbles creates an acoustic field of broadband frequencies that travel through the fluid, allowing for better access to the complex anatomy of the root canal, thereby enhancing disinfection (9-11). Current research has shown that the GentleWave system enables superior bio-film removal in both the main canal and its anatomical complexities compared to passive ultrasonic irrigation (PUI) (12). Additionally, studies have demonstrated its superior anti-bacterial efficacy even in minimally prepared root canal systems, such as #15 .04 (12,13). Interestingly, some studies have found no significant difference in smear-layer removal when comparing the GentleWave system to ultrasonic systems (11,14).

Similarly, OdneClean is a cavitation-based root canal debridement device designed to generate cavitation clouds of imploding micro-bubbles. According to the manufacturer, it should be used with physiological saline solution as the final irrigation to help remove residual tissues, debris, and biofilm from the root canal system after instrumentation. The OdneClean system features a flexible, conical plastic tip measuring 190 microns, which is placed into the main canal during the irrigation procedure. Currently, only one published study has demonstrated its comparable efficacy in biofilm removal compared to syringe needle irrigation and PUI (15). The use of OdneClean with saline irrigation proved effective and comparable to both syringe needle irrigation and PUI when utilizing 3% sodium hypochlorite (NaOCl). However, a combination of 5% NaOCl followed by 17% EDTA showed significantly better smear-layer removal than OdneClean used with saline. Nonetheless, it is important to note that the experimental model used involved dentin discs adhered to the middle third of artificial root canals, which may not accurately reflect the true conditions encountered in actual root canal treatments.

Despite the progress we've made in treatment strategies, we still face a significant challenge: current methods fall short when it comes to restoring the structural integrity of root canal dentin after treatment. This gap underscores the need for innovative solutions that can truly enhance dental care and strengthen tooth structure following procedures. Various physiological, pathological, and iatrogenic factors have been linked to the compromised mechanical strength of restored root-filled teeth (16,17). Additionally, the loss of tooth structure in endodontically treated teeth alters the distribution of stress within the roots, leading to increased stress in the apical region and flexing of the roots, particularly along the buccal-lingual plane (18).

Currently, there are no effective treatments available to counteract the negative effects of disease or treatment-related changes in the root dentin structure of endodontically treated teeth. Research has shown that the human immune system plays a crucial role in the prognosis of endodontic treatments. Root canal therapy aims to minimize bacterial load in the root canal system, allowing our immune system to manage the healing process effectively. To address these issues, the bio-active chitosan nano-technology was developed in our research lab. This approach aims to restore altered root dentin through a micro-tissue engineering strategy, enhancing anti-bacterial efficacy, and promoting wound healing through immune-modulation. Studies have indicated that micro-tissue engineered root dentin, combined with photodynamic-activated cross-linked chitosan nano-particles, can improve the bio-mechanical properties and resistance to fatigue in endodontically treated teeth by stabilizing and strengthening the dentin matrix at the micron level (19).

In animal studies, photo-activated chitosan nano-particles fostered a tissue-repair phenotype in macro-phages, resulting in neo-tissue growth without inflammation or resorption. This suggests effective inactivation of dentin-bound lipopolysaccharides (LPS) and enhanced wound healing. Furthermore, chitosan nano-particle-based treatments have been shown to influence the interaction between periodontal ligament (PDL) fibro-blasts and macro-phages through their modulating effects on inflammatory mediators and transcription factors, thus facilitating macro-phage polarization and promoting PDL fibro-blast migration which enhances immune-modulation and wound healing (22,23).

In conclusion, while clinical studies have not yet confirmed improved prognoses with these advanced technologies due to significant patient variability, it is evident that Er:YAG laser-assisted disinfection and multi-sonic devices have advanced root canal disinfection, especially in minimally prepared root canal systems with complex anatomy. With the future application of non-conventional anti-microbials, such as bio-active anti-bacterial agents combined with immune-modulatory nano-technologies, we anticipate significant improvements in histological healing and the prognosis of endodontically treated teeth, particularly those previously considered to have guarded prognoses.

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