Original Research Paper

Volume - 15 | Issue - 09 | September - 2025 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Dentistry

OVERCOMING THE CHALLENGES OF ROOT CANAL DISINFECTION: A REVIEW

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ABSTRACT The predictable success rate of endodontic therapy has increased its popularity. This is due to the better understanding of the endodontic microbiota and effective techniques developed to combat the same. This paper reviews the various methods and advances available to effectively disinfect the intricate root canals.

KEYWORDS : endodontic disinfection, microorganisms, photon-induced photoacoustic streaming, irrigation, antibacterial nanoparticles

INTRODUCTION

Bacterial colonization of the pulp-dentine complex and the root canal system has been definitively implicated as the primary etiologic factor in pulpal and periapical disease. Elimination of such infections has been the empirical cornerstone of root canal treatment for over a century.[1]

The complexity of the root canal system, presence of numerous dentinal tubules in the roots, invasion of the tubules by microorganisms, formation of smear layer during instrumentation and presence of dentin as a tissue are the major obstacles in achieving the primary objectives of complete cleaning and shaping of root canal systems.

Endodontic Irrigants

Antimicrobial irrigating solutions and other locally used disinfecting agents play a key role in the eradication of microbes. One role of root canal irrigation is to help in the killing of bacteria and the removal of the bacterial biofilm from instrumented surfaces (30–50% of the root canal walls). The various irrigant solutions available are sodium hypochlorite, Chlorhexidine, EDTA, MTAD, citric acid, maleic acid, tetra clean, hydrogen peroxide, and iodine potassium iodide. No irrigant has shown 100% eradication of biofilm conclusively. However, the use of sodium hypochlorite is considered a effective irrigation regimen with concurrent use of other endodontic Irrigants for elimination of endodontic biofilm.[2]

Intracanal Medicaments

Various intracanal medicaments such as calcium hydroxide ($Ca(OH)_2$), Chlorhexidine, ledermix, triple-antibiotics paste, bioactive glass and nanoparticles are being used and investigated for their efficacy in successful elimination of biofilms. Based on the current best available evidence, $Ca(OH)_2$ has limited effectiveness in eliminating bacteria from human root canals when assessed by culture techniques. Most of the studies pertaining to intracanal medicaments are in-vitro which makes the conclusions difficult to extrapolate to actual clinical situations. Triple antibiotic paste (ciprofloxacin, metronidazole and minocycline) and Double antibiotic paste (ciprofloxacin and metronidazole) were more effective than $Ca(OH)_2$ against *E. faecalis* and *P. gingivalis* biofilms.[3]

Lasers

Numerous studies have documented that CO_2, ND: YAG, Argon, Er, And Cr: YAG, and Er: YAG laser irradiation has the ability to remove debris and smear layer from the root canal walls following biomechanical instrumentation.[4] Bactericidal effect of laser is attained by causing changes in bacterial cell wall. Because of the complex three layer membrane, gram negative bacteria are very sensitive to irradiation, and only very small densities of energy result in severe damage to the cell membrane of bacteria. The cell wall of the gram positive *E. faecalis* shows an astonishingly high resistance against the laser irradiation. With the application of multiple irradiations, visible damage of the bacteria can be detected, but there can still be a few unaltered cells. However, the effect is less remarkable than that of NaOCl solution.[5]

Photodynamic Therapy (PDT)

In principle, the strategy utilizes a selectively accumulated or endogenously produced photosensitizer (photoactive compound). The activation of photosensitizer molecules by a specific wavelength of light produces deleterious chemical entities that kill bacteria. The principal agent involved in bacterial killing is the oxygen-based free radical. PDT consisting of methylene blue and a 670-nm diode laser (output power 280 MW during 30 s) or toluidine blue and a 628-nm LED light (output power 1000 MW during 30 s) induced severe damage, including cell lysis, to E. faecalis biofilms. Another study concluded that PDT and the 2.5% NaOCl solution were equally efficient in completely eliminating E. faecalis biofilms at different stages of development.[6,7,8]

Ozone Therapy

Ozone, in the gaseous or aqueous phase, has been shown to be a powerful and reliable antimicrobial agent against bacteria, fungi, protozoa, and viruses. Ozone attacks glycoproteins, glycolipids, and other amino acids and inhibits the enzymatic control system of the cell. This results in increased membrane permeability leading to immediate functional cessation. Ozone gas in a ~4 g/m3 concentration (Heal Ozone; KaVo, Biberach, Germany) is used clinically for endodontic treatments. Studies concluded that the combined use of recurrent doses of topical gaseous ozone with 2% NaOCl enhanced its antibacterial effect against *E. faecalis* biofilm.[9,10]

Plasma Therapy

Non-thermal plasma results in abundant production of reactive species in low gas temperature which includes charged particles, radiation, and reactive oxygen species. These particles play a key role in the removal of biofilms. Non-thermal plasma (NTP) displayed antimicrobial activity against endodontic biofilms in root canals, but was not as effective as the use of 6 % NaOCl.[11]

Photon-induced Photoacoustic Streaming (PIPS)

PIPS is based on the radial firing stripped tip with laser impulses of subablative energies of 20 mJ at 15 Hz for an average power of 0.3W at 50 µs impulses. These impulses induce interaction of water molecules with peak powers o.f 400W. This creates successive shock waves leading to formation of a powerful streaming of the antibacterial fluid located inside the canal, with no temperature rising.[12] Unlike the conventional laser applications, the unique tapered PIPS tip is not mandatory to be placed inside the canal itself but rather in the pulp chamber only. This can reduce the need for using larger instruments to create larger canals so that irrigation solutions used during treatment can effectively reach to the apical part of the canal and also canal ramifications. This procedure can effectively remove both vital and nonvital tissues, kill bacteria, and disinfect dentin tubules. Effect of photon-initiated photoacoustic streaming on removal of apically placed dentinal debris.[13]

Antibacterial Nanoparticles (NPs)

Nanomaterial denotes a natural or manufactured material containing unbound particles in which half or more of the particles in number and size is in the size range of 1-100 nm. These materials present unique physicochemical properties, such as large surface area/mass ratio, and increased chemical reactivity.[14] Nanoparticles synthesized from powders of silver, copper oxide and zinc oxide are currently used and may generate active oxygen species. They are responsible for the anti-bacterial effect by the electrostatic interaction between positively charged nanoparticles and negatively charged bacterial cells. In addition, nanoparticles may change the chemical and physical properties of dentin and reduce the bacterial strength of adhesion to the dentin itself.[15]

Bioactive Glass

Recently, bioactive glass or bioactive glass-ceramics have been a subject of considerable interest for endodontic disinfection owing to their antibacterial properties, but conflicting results have been obtained.[16]

Natural Plant Extracts

A current trend is the use of natural plant extracts, taking advantage of the antibacterial activity of polyphenolic molecules generally used for storing food. These compounds have been found to have poor antibacterial efficacy, but several demonstrate significant ability to reduce the formation of biofilms, although the mechanism by which this occurs is not clear.[17]

Sonic Activation

Sonic activation has shown to be an effective method to disinfect the root canals. Most actual systems have smooth plastic tips of different sizes activated at sonic frequency by a hand piece. This system seems to be able to effectively clean the main canal, to remove the smear layer and to promote the filling of a greater number of lateral canals. [18]Sonic activation differs from the ultrasonic because it operates at a lower frequency (1-6 kHz) , and for this reason it is generally found to be less effective in removing debris than the ultrasonic systems.[19]

Continuous Irrigation During Instrumentation

This system uses a particular instrument with abrasive surface that enlarges the canal by friction and in a vibrating motion allows the irrigant to flow through the file itself. The low cutting efficiency of this system in some cases may limit its use in the root canal preparation. On the other hand, its characteristics make it an excellent additional technique to enhance the cleaning and disinfecting of the root canal system at the end of the preparation.[20]

Gentlewave Irrigation

Gentlewave (GW) (Sonendo, Laguna Hills, CA, USA) system aims to clean the root canal through generation of different physiochemical mechanisms including a broad spectrum of sound waves. Sigurdsson *et al.* reported 97% successful healing in the teeth treated with the GW System at 12 months.[21]

EndoVac® System

The EndoVac® system (Discus Dental, Culver City, Calif.) is a new irrigation system that consists of a delivery/evacuation tip attached to a syringe of irrigant and the high-speed suction source of the dental unit. As the cannulas are placed in the canal, negative pressure pulls irrigant from a fresh supply in the chamber down into the canal to the tip of the cannula, then into the cannula and finally out through the suction hose. [22]These findings point to the importance of the use of antiseptic irrigants in addition to mechanical vibrations and application of negative pressure during cleaning and shaping of root canals.

CONCLUSION

To date, many methods and antibacterial agents have been proposed against biofilms that are effective within a wide range of activity. However, no technique has shown 100% elimination of the root canal microbiota conclusively. The irrigants that are currently used during cleaning and shaping include NaOCl, CHX, EDTA and MTAD. None of these irrigants has all of the characteristics of an ideal irrigant. Sonic and ultrasonic vibrations alone or in combination with antibacterial irrigants as well as application of negative pressure have been used to increase the efficacy of these irrigants. Intracanal medicaments have been used to disinfect root canals between appointments and reduce interappointment pain. Model development and studies are needed to explore the conditions that may affect the efficacy of endodontic anti-microbial *in vivo* so that their clinical effect can be better predicted.

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