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Review Article

From Gut to Pulp: Translating Systemic Probiotic Benefits into Endodontic Practice

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Abstract: The Oral cavity is an ecosystem as intricate and significant as the gut, according to recent discoveries about the human microbiome. In endodontics, microbial dysbiosis in the root canal system is a major cause of apical periodontitis, which is usually resistant to traditional disinfection because of hardy biofilms and enduring pathogens like Candida albicans and Enterococcus faecalis. The rising translational use of probiotics in endodontic therapy is examined in this article, which moves the emphasis from indiscriminate bacteria eradication to ecological modulation and biofilm interference. By competing for adhesion sites, modifying cytokines, and disrupting biofilms, probiotics, which are defined as live bacteria that provide antimicrobial, anti-inflammatory, and tissue-regenerative effects. By introducing non-pathogenic, biofilm-compatible bacteria to outcompete pathogens and aid in healing, the idea of "effector strains" provides a focused strategy. Probiotic integration into root canal systems is being studied using a variety of delivery methods and are suggested as a promising adjuvant in the quest for long-term endodontic success.

Keywords: Probiotics, E. Faecalis, Microbiome, Root Canal Treatment.

Introduction

The human microbiome, a dynamic and diverse microbial ecosystem found in the human body, is essential to preserving systemic health. Although the gastrointestinal tract has long been recognized as a central hub for microbial activity and probiotic intervention, recent advances in microbiology have emphasized the equally significant role of the oral microbiome. Much like the gut, the oral cavity harbors a complex microbial community. Much like the gut, the oral cavity harbors a complex microbial community [1,2].

Oral bacteria infiltrate the pulp and root canal system as a result of dental caries, resulting in apical periodontitis (Nair, 2004; Fujii et al., 2009). Apical periodontitis is polymicrobial, with anaerobic Gram-negative species predominating [3]. Nevertheless, persistent endodontic infections typically involve Enterococcus faecalis and Candida albicans. These organisms are often embedded within treatment-resistant biofilms, making apical periodontitis a biofilm-induced pathology [4].

Conventional endodontic therapy emphasizes chemo-mechanical debridement and disinfection of root canal to eliminate all microorganisms from the canal system (Gomes et al., 2004). This approach, however, ignores the ecological complexity of the canal, where disease progression is influenced by interspecies interactions and microbial succession [4]. The understanding that not all bacteria are pathogenic and that some may even aid in tissue repair and ecological balance is causing a paradigm shift [5].

In this regard, probiotics offer a microbiome-centered therapeutic strategy. Based on their proven benefits for gastrointestinal health, probiotics are currently being investigated in endodontics to modulate dysbiotic microenvironments, suppress pathogenic biofilms, and support host immune responses. Considering the drawbacks of traditional disinfection techniques and the impossibility of attaining total sterility, this translational application of probiotics may enhance long-term clinical outcomes [6,7].

Probiotics: Definition and Mechanisms of Action

The World Health Organization defines probiotics as "live microorganisms which, when administered in adequate amounts, confer a health benefit on the host [1]."

Their mechanisms of action include [8,9,1]:

1. Bacteria's competing for nutrients and adhesion sites.
2. Preventing the growth of biofilms and structural instability, which makes pathogenic communities more amenable to intervention.
3. The elevation of anti-inflammatory mediators (IL-10, secretory IgA) and the downregulation of pro-inflammatory cytokines (IL-1β, TNF-α, and IL-8) (Geier, 2007).
4. Supporting tissue regeneration by regulating apoptosis and promoting cell repair pathways.

Delivery of Vehicles for Probiotics

Probiotics are incorporated into various delivery systems, including C

1. **Functional Foods and Drinks:** Fruit juices and fermented goods that include probiotic cultures.
2. **Symbiotic Formulations:** Added to prebiotic fibers to improve efficacy and colonization.
3. **Dairy-Based Products:** Probiotic viability and palatability are supported by yogurt, milk, and fermented beverages.
4. **Non-Dairy Supplements:** Probiotic formulations in powdered or encapsulated form that are appropriate for people with dietary limitations.

Common Probiotic Species [1,7]:

- **Lactic Acid Bacteria:** *Lactobacillus acidophilus, L. casei, L. rhamnosus, L. reuteri.*
- **Bifidobacteria:** *B. bifidum, B. lactis, B. longum.*
- **Non-Lactic Acid Bacteria:** *Enterococcus faecium, Streptococcus thermophilus.*
- **Non-Pathogenic Yeasts:** *Saccharomyces boulardii.*

Probiotics in Endodontics: A Translational Perspective

The use of probiotic formulations as an adjunct for traditional irrigants and intracanal medications in endodontics is supported by recent research. Lactobacillus acidophilus and Bifidobacterium bifidum were the first probiotic species to be used in studies [1]. Various studies concluded that probiotic formulations containing Lactobacillus, Bifidobacterium, and Streptococcus species have inhibitory effects on these pathogens. Crucially, cell-free supernatants also exhibit antimicrobial activity, suggesting that metabolites by themselves can have therapeutic effects [2]. The production of reuterin and reutericyclin by Lactobacillus reuteri inhibits DNA synthesis in a variety of pathogens. By altering quorum sensing and gene expression, lipoteichoic acid, which is secreted by Lactobacillus plantarum, prevents the production of biofilms. L. acidophilus and L. rhamnoses have been demonstrated to decrease inflammation and enhance healing-promoting cytokine profiles when administered systemically in mouse models [1,10].

The translational use of probiotics in endodontics is grounded in the concept of using "effector strains". The term "effector strain" describes a microorganism, frequently a genetically altered strain that is injected into a host to stop a disease-causing pathogen from infecting it. In essence, it's a "replacement therapy" strategy in which the effector strain fills the niche that the pathogen would typically occupy, stopping the pathogen from causing illness [11,1].

Proposed ideal requirements of effector strains to have probiotic effects in the oral cavity are [1,9,10,11]:

1. Non-pathogenic and non-cariogenic: A successful effector strain for bacterial illness replacement therapy must not induce the disease or otherwise disrupt the host's living ecology, increasing the host's chance of contracting further disease states (Hillman et al., 2000).
2. Strong adherence to the root canal environment's dentin surfaces to initiate colonization and integrate into the biofilm (Knuuttila, 2006).
3. A substantial degree of genetic stability is required (Hillman et al., 2000).
4. Able to prevent the production of biofilms or disrupt existing ones.
5. Resistance to the low nutrition availability, alkaline pH, and anaerobic or microaerophilic conditions common in root canal systems.
6. Compatible with contemporary intracanal medicament, irrigants (e.g., NaOCl, EDTA), and obturation materials.
7. Encourage healing by modulating the expression of cytokines (e.g., TGF-β, IL-10.
8. Able to modulate local immune responses, reduce inflammation in periapical tissues, and promote healing.

Probiotic Delivery Vehicles in Endodontics

The following are the frequently investigated or suggested methods of probiotic delivery in endodontics.

A. Intracanal Medicaments [12,1,6,7]:

- **Hydrogels (e.g., chitosan, alginate):** Biocompatible, allow slow release.
- **Calcium Hydroxide Paste:** Dual mechanism, high pH and probiotic activity.
- **Carboxymethylcellulose (CMC) Gel:** Stabilizes probiotic viability.
- **Poloxamer 407:** Liquid at room temp, gels at body temperature; sustains microbial viability for up to one week (Bohora et al., 2022).
- **Methylcellulose/HPMC:** Enhances intracanal adhesion and contact time.
- **Nanoparticle Encapsulation:** PLGA-based systems offer targeted, controlled delivery currently experimental.

B. Endodontic Irrigants [13]:

- **Probiotic Suspensions** in PBS or saline.
- **Probiotic-Enriched Herbal Extracts** (e.g., neem, green tea).
- **Electrochemically Activated Solutions:** Improve probiotic stability and efficacy.
- **Skimmed Milk/Milk Media:** Stabilizing environment, rarely used due to nutrient availability for all microbes.
- **Bioactive Glass Suspensions:** Combine antimicrobial and remineralization properties, experimental phase.

Challenges and Future Direction

Current evidence indicates that probiotic effects are strain specific, meaning that even if two strains are members of the same species, one strain cannot provide the same beneficial impact as another [1]. Hence, their application in endodontics presents unique challenges:

- Identification of strains with targeted efficacy against resistant pathogens.
- Optimization of delivery vehicles for intracanal environments.
- Establishing standardized dosages, application protocols, and treatment durations.
- Validation through rigorous in vivo and clinical trials.

Research must focus on refining these strategies to achieve predictable, reproducible outcomes that can be seamlessly integrated into existing clinical practice. The use of probiotics in regenerative endodontics could be a promising alternative to triple or double antibiotic paste, offering a potential solution to the issue of antimicrobial resistance, a topic that remains underexplored.

Conclusion

The integration of probiotics into endodontic therapy signifies a transition from eradication-based strategies to ecological modulation. This microbiome-conscious approach aligns with contemporary principles of host-microbe symbiosis and biological healing. With further research, probiotics may emerge as a valuable adjunct in managing persistent infections and enhancing the predictability of endodontic success.

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