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Short Communication

Bacteriophage-enabled oral imaging: A dual-function strategy for microbial and cancer diagnostics and therapy

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Abstract

Bacteriophages (phages), the natural predators of bacteria, are emerging as innovative tools in diagnostic imaging and precision therapy. In the oral cavity, where microbial infections and oral cancers are significant clinical concerns, phage-based strategies offer a non-invasive, targeted approach for both detection and treatment. This short communication explores the convergence of bacteriophage technology and oral imaging for early microbial diagnosis and treatment, while also highlighting evolving applications in imaging and targeted therapy for oral cancer.

Keywords: Bacteriophage, Oral imaging, Microbial diagnosis, Oral cancer, Theranostics, Phage therapy, Dental biofilm, Targeted therapy.

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1. Introduction

Oral diseases such as dental caries, periodontitis, and oral cancer remain major global health burdens.[1,2] Traditional diagnostics rely on culture methods or invasive biopsies, which are often time-consuming, lack specificity, or are limited in spatial resolution.[3] Bacteriophages offer a novel biological platform with high specificity for target bacteria and, through engineering, can be adapted for molecular imaging or targeted drug delivery.[4-6] This communication highlights the dual potential of phages in oral microbial diagnostics and in the emerging field of oral cancer imaging and treatment.

2. Phages in Microbial Diagnosis, Therapy and Oral Cancer Imaging

Bacteriophages, long recognized for their therapeutic efficacy in treating bacterial infections—including ocular infections[7] —can be engineered to selectively detect and eliminate pathogenic bacteria within the oral microbiome, such as *Streptococcus mutans*, *Enterococcus faecalis*, and *Porphyromonas gingivalis*. Phage-derived proteins (e.g., endolysins) and intact phage particles can be conjugated with fluorescent markers or nanoparticles to enhance diagnostic and therapeutic precision. By harnessing the unique optical, electrical, and magnetic properties of nanoparticles,[8] these phage-nanoparticle conjugates hold significant promise as contrast agents for imaging dynamic molecular processes. Coupled with the inherent targeting specificity of bacteriophages, they can selectively bind to microbial or host cells, enabling their application in real-time imaging technologies such as fluorescence-based oral cameras and optical coherence tomography (OCT).

Beyond microbial diagnostics, recent research has demonstrated the potential of phages as tumor-targeting vectors.[9] Both fluorescence imaging and OCT are non-invasive, effective tools for the early detection and

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monitoring of oral cancers and precancerous lesions. Although they do not replace biopsy as a definitive diagnostic method, they provide valuable support in screening, early diagnosis, and guiding biopsy site selection.[10] Phage display libraries allow for the identification of peptide ligands that bind specifically to tumour-associated markers such as epidermal growth factor receptor (EGFR) and CD44—both commonly overexpressed in oral squamous cell carcinoma (OSCC).[11] These engineered phages can be conjugated with contrast agents for imaging modalities including near-infrared fluorescence, Positron Emission Tomography, and Magnetic Resonance Imaging, enabling high-specificity visualization of neoplastic lesions. This approach may significantly enhance early detection, intraoperative imaging, and surgical margin assessment in OSCC.

In addition to diagnostics, phage nanoparticles offer promising therapeutic potential. They can serve as targeted delivery systems for anticancer drugs or photothermal agents, enabling localized treatment with minimal off-target effects.[12] In clinical settings, fluorescent phages could facilitate chairside diagnosis of bacterial biofilms, improving detection of early-stage infections in periodontal pockets, around implants, or within root canal systems. Concurrently, lytic phages may be deployed therapeutically to reduce bacterial load, offering a particularly valuable strategy in managing antibiotic-resistant infections.

3. Theranostic Potential and Integration into Clinical Practice

The integration of diagnostic and therapeutic capabilities—termed *theranostics*—is a major advantage of phage-based systems. In one approach, a phage could detect and label pathogenic bacteria or cancer cells in the oral cavity and simultaneously deliver an antimicrobial peptide or cytotoxic drug. Such multifunctionality could transform personalized dentistry and oncology by enabling real-time, image-guided intervention.

4. Challenges

Challenges include optimizing phage stability in the oral environment, regulatory concerns, and the need for large-scale clinical validation. However, advances in synthetic biology, bioengineering, and imaging technology are rapidly addressing these limitations.

5. Conclusion

Bacteriophage-based imaging and therapy represent a powerful, dual-function platform for precision diagnostics and treatment in oral health. By enabling the targeted detection of pathogenic bacteria and early-stage oral cancers, and offering tailored therapeutic interventions, phage technology is poised to transform diagnostic dentistry and oral oncology. Further interdisciplinary research and clinical trials will be key to realizing its full potential.

6. Source of Funding

None.

7. Conflict of Interest

None.

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