

**ENDOCATOR AND ATP BIOLUMINESCENCE TECHNOLOGY: A NOVEL
PARADIGM FOR OBJECTIVE ASSESSMENT OF ROOT CANAL DISINFECTION – A
REVIEW ARTICLE**

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ABSTRACT

The success of endodontic treatment depends largely on the effective elimination of microorganisms, necrotic tissue remnants, and organic debris from the root canal system. Despite significant advances in instrumentation and irrigation protocols, clinicians still lack an objective chairside method to verify canal cleanliness before obturation. Currently available assessment techniques, including microbial culture, polymerase chain reaction, and microscopic analysis, are predominantly research-based tools and are not routinely applicable in clinical practice. Recently, ATP bioluminescence technology has emerged as a promising method for rapid assessment of residual biological contamination within root canals.^[1,10,11] Endocator is a novel ATP-based chairside diagnostic system that measures ATP-related bioluminescence signals to quantify residual biological material and generate an objective cleanliness score.^[1,5] This narrative review discusses the biological basis of ATP bioluminescence, the operating principle of Endocator, currently available laboratory and clinical evidence, potential applications in endodontic practice, advantages, limitations, and future directions.^[1-5] Current evidence suggests that ATP-based assessment may enhance clinical decision-making by providing an objective measure of root canal cleanliness before obturation.^[1]

KEYWORDS: Endocator, ATP bioluminescence, root canal disinfection, canal cleanliness, microbial assessment, endodontics.

1. INTRODUCTION

Microbial infection of the root canal system remains the principal etiological factor in the development and persistence of apical periodontitis. Successful root canal treatment therefore relies on the effective reduction of microorganisms and their by-products through chemo-mechanical preparation and irrigation.^[6,8,9] Despite advances in nickel–titanium instrumentation, irrigation activation devices, and intracanal medicaments, complete decontamination of the root canal system remains challenging because of anatomical complexities such as fins, isthmuses, accessory canals, and dentinal tubules.^[6-9]

A major challenge in endodontic therapy is the inability to objectively determine whether adequate canal disinfection has been achieved before obturation.^[1,11] Clinicians generally rely on treatment protocols, canal dryness, and clinical judgment rather than direct biological verification of cleanliness.^[1] This has stimulated interest in technologies capable of providing real-time information regarding residual contamination within the canal system.^[1,11]

ATP bioluminescence has been widely used in healthcare and environmental monitoring as a rapid indicator of biological contamination.^[1,10] ATP is present in all living cells and functions as the primary intracellular energy carrier. ATP detection is therefore considered an

indicator of viable biological material.^[1,2,10] The adaptation of this technology to endodontics has led to the development of Endocator, a chairside ATP bioluminescence device designed to quantify residual biological material within root canals.^[1,5] By providing a numerical cleanliness score within seconds, Endocator has the potential to transform the assessment of root canal disinfection and move endodontic practice toward more objective and evidence-based treatment endpoints.^[1,5]



2. Biological Basis of ATP Bioluminescence

ATP serves as the universal energy currency of living cells and is present in bacteria, fungi, human cells, and other biological tissues. Because ATP rapidly degrades following cell death, its presence is widely accepted as a marker of viable biological material. ATP bioluminescence technology is based on the luciferin–luciferase reaction, in which ATP serves as a substrate that produces measurable light emission. The intensity of the emitted light is proportional to the amount of ATP present and is expressed as relative light units (RLUs).^[2,10]

Within the root canal environment, ATP may originate from viable microorganisms, residual pulp tissue, inflammatory exudates, or organic debris.^[1,2] Consequently, ATP measurement provides an indirect assessment of the biological burden remaining after instrumentation and irrigation. Unlike culture-based techniques, ATP testing does not require microbial growth or laboratory processing, making it suitable for chairside use.^[1,5,10]

3. Conventional Methods for Assessing Root Canal Disinfection

Several techniques have traditionally been employed to evaluate the effectiveness of root canal disinfection.^[1,7,8] Microbial culture methods have historically been considered the reference standard for detecting viable bacteria; however, they are time-consuming and incapable of identifying many non-cultivable species.^[1,7,8] Molecular methods such as polymerase

chain reaction offer greater sensitivity but cannot consistently distinguish between living and dead microorganisms.^[1,7,8] Scanning electron microscopy and confocal laser scanning microscopy provide valuable information regarding debris removal and bacterial distribution but are restricted to laboratory settings and cannot be used during routine treatment.^[1]

These limitations highlight the need for a rapid, objective, and clinically practical method for assessing canal cleanliness during treatment.^[1,11]

4. Principle and Working Mechanism of Endocator

Endocator applies ATP bioluminescence technology specifically to endodontic procedures.^[1,5] Following canal preparation, a sample is collected from the root canal and analyzed using a bioluminescence-based reaction capable of detecting ATP, ADP, and AMP.^[5] The generated luminescent signal is converted into a quantitative score that reflects the amount of residual biological material within the canal.^[1,5]

Lower values indicate cleaner canal conditions, whereas higher values suggest the presence of remaining biological contamination.^[1,5] One of the major advantages of the system is the speed with which results are generated, allowing clinicians to assess the effectiveness of cleaning procedures immediately before obturation.^[1,5]

ENDOCATOR SCORE (ES)

Parameter	Details
Measurement Modes	ES (Endocator Score), RLUs
Scale Range	0 – 100
0 Value	Clean canal
100 Value	Highly contaminated canal

CLINICAL INTERPRETATION

ES Value	Status	Meaning
0 – 30	Clean	Adequate disinfection
31 – 60	Contaminated	Needs further cleaning
61 – 100	Dirty	Poorly cleaned canal

Rapid Chairside Assessment Tool

5. Evidence Supporting Endocator Technology

Arcuri and colleagues demonstrated that Endocator possesses high sensitivity and reproducibility for differentiating contaminated and cleaned root canal environments under controlled laboratory conditions.^[5] Their findings supported the potential use of ATP

bioluminescence as a quantitative indicator of canal cleanliness.^[5]

Subsequent investigations by Bolla and co-workers evaluated the effectiveness of sonic activation systems using ATP-based assessment.^[2] These studies showed significant reductions in ATP values following activation procedures, indicating improved removal of biological debris from root canal systems.^[2] Clinical investigations further confirmed that ATP bioluminescence testing can detect differences between irrigation protocols and may be useful for comparing the effectiveness of various disinfection strategies.^[3,9]

More recently, Kennelly *et al.* evaluated irrigant activation systems using a chairside quantitative assay and reported improved organic debris removal with activated irrigation approaches.^[4] Collectively, these findings suggest that ATP-based testing can serve as a practical tool for evaluating root canal cleanliness in both research and clinical environments.^[2-5]

6. Clinical Applications

- Assessment of irrigation effectiveness.
- Comparison of activation techniques.
- Evaluation of intracanal medicaments.
- Validation of emerging disinfection technologies.
- Standardization of endodontic research protocols.
- Objective assessment before obturation.

The ability to obtain real-time information regarding canal cleanliness may support more individualized treatment decisions and improve the consistency of endodontic procedures.^[1,3]

7. Advantages and Limitations

Advantages

- Rapid chairside analysis.
- Quantitative and objective results.
- Minimal disruption to clinical workflow.
- Useful for comparative research.
- Potential to improve treatment standardization.
- Supports evidence-based decision-making.

Limitations

ATP measurements reflect total biological contamination rather than specific microbial species.^[1,5,10] Consequently, the technology cannot identify individual pathogens or determine microbial virulence.^[1] Residual ATP may also originate from non-microbial organic tissues, which can influence recorded values.^[1,5] In addition, clinically validated threshold values for defining adequate canal cleanliness remain to be established.^[1] Current evidence is promising but remains limited, emphasizing the need for larger multicenter clinical studies.^[1,5]

8. Future Perspectives

The future of ATP-based diagnostics in endodontics lies in the development of standardized clinical thresholds and the establishment of correlations between ATP values and treatment outcomes.^[1,3,4] Integration with digital dentistry platforms and artificial intelligence may further improve interpretation and clinical applicability.¹ As evidence expands, ATP bioluminescence testing could become an important component of precision endodontics.^[1]

9. CONCLUSION

Endocator represents an innovative application of ATP bioluminescence technology for the chairside assessment of root canal cleanliness.^[1,5] Available laboratory and clinical evidence indicates that the technology is capable of providing rapid, reproducible, and quantitative information regarding residual biological contamination within root canals.^[2-5] Although further research is necessary to establish definitive clinical thresholds and outcome correlations, Endocator offers a promising step toward objective verification of root canal disinfection and may contribute to more predictable endodontic treatment outcomes.^[1]

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