Anil Kishen
Editor

Nanotechnology in Endodontics

Current and Potential Clinical Applications

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This book is dedicated to my teachers, students, colleagues and family for making a difference.

Anil Kishen

Preface

Current understanding emphasizes that endodontic disease is a biofilm-mediated infection. Therefore, elimination of biofilm bacteria from the root canal system remains to be the primary focus in the management of endodontic disease. Unfortunately, the endodontic environment is a challenging locale to eliminate surface-adherent biofilm bacteria. This advanced antimicrobial strategies are required for the optimal disinfection of previously infected root canal system. This step is crucial not only to predictably perform conventional root can treatments but also to develop tissue engineering–based strategies that can achieve organized repair or regeneration in previously infected teeth.

Nanotechnology is a rapidly advancing interdisciplinary field, and the use of nanomaterials is becoming more and more common for different healthcare purposes. Generally, nanomaterial-based approaches present distinct advantages over conventional approaches. At the nanometre scale, the characteristics of materials appear to be markedly different to those of the same material at the macro scale. Nanotechnology/nanoparticles in endodontics can offer different benefits, ranging from efficient miniaturization techniques to approaches that control the molecular assembly, all of which can create exciting opportunities for the prevention, diagnosis and treatment of endodontic disease.

This book is aimed to provide a comprehensive understanding of the current and potential application of nanoparticles in endodontics. Chapters 1, 2, and 3 cover the fundamental aspects of nanomaterials, with potential applications in endodontics. The basis of nanotechnology and nanomaterials in tissue engineering, methods for characterizing nanomaterials/nanoparticles, techniques to assess the cytotoxicity in nanomaterials/nanoparticles and the basis of nanomaterials/nanoparticles in drug and gene delivery are covered in these chapters. Chapters 4, 5, 6, and 7 deal with the applications of nanoparticles that are more specific to the field of endodontics. Antibacterial nanoparticles, nanoparticles for dentin tissue stabilization, nanoparticles in restorative/endodontic materials and the application of nanomaterials for minimally invasive treatment of dental caries are covered in these chapters.

This book is intended for graduate students and practising clinicians with interest in the new and exciting field of nanomaterials/nanoparticles.

Toronto, ON, Canada — Anil Kishen, BDS, MDS, PhD

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Introduction

1

Shimon Friedman

Abstract

This new textbook on current and potential applications of nanotechnology in endodontics is offered to the endodontic community at a juncture when there is emerging understanding that traditional endodontic therapy may be limited in its ability to cure apical periodontitis and retain treated teeth. Improvements in treatment outcomes have been elusive, suggesting that "out of the box" approaches are needed beyond conventional endodontic therapy and restorative concepts.

Dr. Kishen's textbook offers the first focused glimpse at nanomaterials harnessed for root canal disinfection and stabilization of root dentin to overcome the microbial resilience, the ultimate challenge in endodontic therapy, and to enhance the resistance of root dentin to cracking. It provides an insight into how emerging nanotechnologies may benefit teeth and patients. Because of its focus on emerging innovative technologies, the content of this textbook and its detailed analysis are not yet found in any of the other endodontic textbooks. In this regard, it is a most timely addition to the endodontic texts which will become a valuable resource for endodontic clinicians and researchers.

This new textbook on current and potential applications of nanotechnology in endodontics by Dr. Anil Kishen is presented to the endodontic community at a juncture when there is emerging understanding that traditional endodontic therapy may be limited in its ability to cure apical periodontitis and retain treated teeth. Suffice it to observe that the clinical mid-term (4–10 year) treatment outcomes reported in literature from 50 to 60 years ago [1–5] and in current literature [6–8] are comparable [9, 10], to have one wonder whether they can indeed improve. This may be disappointing to many who consider that the elapsed decades, and especially the past 20 years, have brought along remarkable development of endodontic technologies, representing one of the most rapid and extensive technological evolutions in all of dentistry.

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The passage of time has allowed improved understanding of endodontic disease and its primary cause, the modalities applied to address that cause as well as the limitations of those modalities. Driven by an ever-increasing volume of research, this process has seen several shifts in focus that, in turn, have generated technological advances that improved almost every aspect of how endodontic therapy is delivered. The rapid pace of those advances challenged the endodontic community to keep up both with the changing focus and the technologies developed to improve endodontic therapy.

And yet, major breakthroughs in improving treatment outcomes have been elusive, suggesting that novel, 'out-of-the-box' approaches may have to be explored beyond the conventional concepts of canal disinfection and filling as well as tooth restoration. Dr. Kishen's textbook offers the endodontic community the first focused glimpse at nanotechnology that can be considered 'out of the box' when compared with existing endodontic therapeutic approaches.

Nanomaterials are being adapted to be harnessed in root canal disinfection and stabilization of root dentin in response to the emerged understanding that canal disinfection cannot be predictably achieved in all treated teeth even when using the most recent protocols and that root dentin in treated teeth may be vulnerable to cracks. The goals are to overcome the microbial resilience that represents the ultimate challenge in endodontic therapy and to enhance the resistance of root dentin to cracking and in so doing to circumvent the traditional reliance on just endodontic instruments and irrigation with topical antiseptics to reach anatomical intricacies of the root canal systems and dentinal tubules.

Development of nanomaterials towards potential applications in endodontics to address the above challenges is far from elementary. It requires specific knowledge to drive unique adaptations of nanotechnologies but also updating the clinicians on how nanotechnologies may be applied in practice. Compiling a textbook that captures emerging innovations and concepts is a challenge in itself. The biggest risk is that the emerging technologies will evolve rapidly, rendering the textbook obsolete shortly after it is published. Faced with this risk, for the textbook to still provide value to readers, it needs to provide the comprehensive background on the novel technologies, what they are intended to achieve and the concepts of how they are expected to achieve those goals.

Dr. Kishen's textbook is designed specifically to provide the knowledge base, the detailed information on current and emerging nanotechnologies and insight into how those nanotechnologies may benefit teeth and patients. In this regard, this textbook is a most timely addition to the endodontic texts available to clinicians and researchers.

Dr. Kishen teamed up with a carefully selected panel of experts, allowing the reader to benefit from their cumulative expertise. With access to this collective expertise, the reader gains an in-depth insight into the current state of nanotechnologies as they may apply to disinfection of root canal systems and stabilization of root dentin. Because of its focus on emerging innovative technologies, the content of this textbook and its detailed analysis are not yet found in any of the other endodontic textbooks.

This textbook is organized in a logical sequence. Rather than assigning precedence to clinical applications in endodontics, the book first reviews the foundations of nanotechnology and nanomaterials as they evolved in the domain of tissue engineering. It is this domain after all that provided much of the inspiration to exploring potential benefits of nanotechnology in endodontics. This is then followed by characterization of nanomaterials with regard to their size, physical and chemical properties, their interactions with biomolecules such as proteins and membrane receptors and their cytotoxicity and its implications on safe application. The possibilities of drug and gene delivery are reviewed next, covering a range of applications in health care but also in periodontal and endodontic therapy. Only after this knowledge base is provided is the focus on applications in endodontic therapy introduced, primarily to enhance disinfection of the root canal system. Next reviewed is the potential application of nanomaterials in stabilization of root dentin with the aim of reducing its susceptibility to crack formation. The scope of the textbook is then further expanded to include applications of