Image-Guided Endodontics: The Role of the Endodontic Triad

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INTRODUCTION

For hundreds, if not thousands, of years, there was universal agreement on the Cosmological Triad of the Heavens (shamayim), the Earth (erets), and the Underworld (sheol). According to the Flat Earth Society, the Earth is floating on water, with heaven above and the underworld below. Some still believe this triad today, citing scientific experiments, evidence, and experience that demonstrates the earth is flat.1,2

With little change, one can see the parallels in endodontics dominated by the Endodontic Triad for Success during the past 50 years based on “shaping canals, cleaning in 3 dimensions, and filling root canal systems.”3-5 The quintessential goals of endodontic procedures have been stated to be elimination of organic substrate and bacteria and filling root canal systems,4 as the purpose of endodontics has been stated to be the prevention or treatment of apical periodontitis.5,6,7,8,9 Throughout the decades, 2 broad schools of thought3 have emerged prescribing the intervention parameters that are thought to best achieve these treatment objectives. Shaping was accomplished by the use of sharp, stiff, untapered, unforgiving stainless steel hand instruments. Cleaning was done by hand with passive irrigation. The case was then packed by hand, generally using multiple waves of pluggers or spreaders and cones. However, the focus of both camps has always been on eliminating the bacteria (Figure 1).

The observations of the surviving stream of long-term, 20-plus year surviving cases present a completely different picture than either camp would allow. The surviving cases as a group are devoid of evidence of any of these traditionally required procedural objectives from either camp (Figure 2).

This presents difficulties for endodontists and endodontics as these observations contradict the scientific pillars used to support treatment protocols such as the Five Mechanical

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About the Authors

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Objectives, Washington Monument, and others, all based on the constructs of the Endodontic Triad for Success. This cognitive dissonance was raised 50 years ago in the seminal paper by Seltzer and Bender that would do all endodontists well to read again. Nature seems to have a different triad (Figure 3).

Regardless of the philosophical camp, endodontic access, shaping, and size have been foundationally prescriptive in nature, ascribing geometric form and approaches irrespective of individual morphology. Protocols have been based on the tooth type, not specifically tailored, nor executed in appreciation of the morphologic and anatomic uniqueness routinely encountered. They have been drawn as if we were treating intact, unrestored, caries-free teeth. Many of these geometric forms, instruments, and procedural steps have not changed in more than 50 years!

Courses that continue teaching clinical techniques ask participants to bring “already accessed teeth.” This bypasses one of the most important steps and illustrates the focus on the endodontic objectives while being unaware of the restorative consequences. Subsequent steps are performed with a set of instruments in a prescribed order and then those protocols are deployed on the wide range of variability in the clinician’s population of patients.

Tailoring Care: Image-Guided Treatment

Precision medicine (PM) refers to the tailoring of medical treatment to the individual characteristics of each patient. Imaging has become a crucial part of PM during the last decade. PM takes into account and aims to exploit the specific profile of the patient’s unique biology and problem. Imaging plays an important role by providing morphologic and functional information, focusing and guiding treatment and assessing response to therapy. Image-guided treatment (IGT), or here specifically image-guided endodontics, is not a strategy that tries to optimize 3-D cleaning, shaping and disinfection, and filling root canal systems. It does not have a “role” for the traditional Endodontic Triad any more than a flat earth has a role in the Heliocentric model. This is not an update on traditional endodontic access, or shape/clean/pack as the authors believe the traditional approach to endodontic access is fundamentally flawed. Importantly, IGT is not about simply making a smaller access or smaller shape. It is about strategic dentin preservation (Figure 4). It is about restoring balance. It is about planning access, planning shape using a directed approach, and evaluating the response to treatment. Traditional endodontic treatment has been convenience-driven and endodontic-centric, primarily focused on operator needs, and has been decoupled from the restorative needs and tooth needs.
In the Viewpoint article in this issue, the authors (including the lead author of this article) review the history of our science and its progression, and why endodontists struggle so much with what is often immediately obvious to the restorative dentist.

Why We’ve Been Stuck For 50 Years
Scientific progress is generally hindered by trying to take the past into account as a way to move forward. The elimination of bacteria, an unreasonable and unachievable endpoint, has become the objective of endodontic treatment with clinicians and educators going so far as to say that prevention or removal of microbes from the root canal system is the factor that determines if the treatment will be successful or not. What if that is not why cases are successful? We have been misled by culturing, mistaking lack of evidence of growth for “removed” or “killed” or “bacteria-free.” Microbial dormancy may result from the formation of persister cells as well as viable-but-non-culturable cells that resist traditional culturing techniques. It is likely then, that our success may come more from altering the microbial environment and inducing bacterial dormancy as opposed to killing and removal. Perhaps a different, more conservative set of procedural objectives might be sufficient to induce dormancy? Considering dormancy as a possible explanation, one may now appreciate how cases shown in Figure 2 may be working despite not having achieved the biomechanical requirements of the Endodontic Triad. Furthermore, microbial dormancy and the persistence model suggest that all these efforts directed toward reduction or removal may have done little or nothing to improve outcome. Instead, they have come at the cost of competing considerations, including structural and restorative considerations, which are likely more important for long-term tooth preservation. Our thinking was constrained by our biological understanding of disease, our materials, instruments, and techniques. Even as materials,
Image-Guided Endodontics: The Role of the Endodontic Triad

Instruments, and techniques progressed, our thinking stayed the same. Einstein is quoted as saying, “We can't solve problems by using the same kind of thinking we used when we created them.” The authors view the continued controversy as to the minimal mechanical requirements for achieving disinfection as an immaterial distraction, as these philosophical debates stem from a disinfection-based biological model of endodontics derived from a Kochian, planktonic, acute-disease view of apical periodontitis with the traditional goal of endodontic treatment being to prevent or cure apical periodontitis. The authors in this article see endodontics as a branch of restorative dentistry whose primary purpose is the preservation of the natural dentition for the length of a patient's life.

The intention of this article is threefold:

1. To invite readers to take a critical look at the cases in their own practice that are surviving 20-plus years and see if the requirements of the Endodontic Triad for Success have been met.
2. To introduce a new Endodontic Triad based upon the evidence present in the actual stream of long-term surviving cases.
3. To introduce the language, thinking, and armamentarium available that we believe adequately addresses both the old and new Endodontic Triads.

We wish to introduce the language and concepts on some prototypical cases to show what a growing minority of endodontists are thinking and where endodontics is heading. The viewpoint article reviews where endodontics has been and introduces the principles and reasons why this growing minority has adopted these ideas. The reader is referred to Best Practices in Endodontics: A Desktop Reference for a more complete description of the clinical techniques.

The New Endodontic Triad
The convergence of 3 pieces of technology has allowed a complete shift in the practice of endodontics: the microscope; low-dose focused field CBCT; and root-form appropriate, heat-treated NiTi instruments. This new triad is now focused not on removal of bacteria, but on preservation of the pericervical dentin (PCD). The microscope allows the preparation of a much smaller and more precise access. Dramatically smaller than traditional access, often individualized per root, or even per canal. Of course these smaller accesses might hinder the clinician's ability to locate clinically relevant anatomy, and have been a primary objection to the minimally invasive strategy. Second, very, very small shapes are cut with coronally conservative, heat-treated NiTi and Ca(OH)₂ placed in the prepared canals. These root-form appropriate variable taper files allow for safe and effective instrumentation and obturation of canals without unnecessarily weakening the tooth. Some might bring up the concern that these smaller shapes might hinder the clinician's ability to “cleanse and shape the canal properly.” Third, the in-office CBCT is the last but crucial piece of the puzzle.

These legitimate concerns are addressed by IGT. An interim or mid-treatment CBCT study can be ordered to allow the clinician to inspect the case nondestructively for possible undiscovered anatomy as the already addressed anatomy is readily demonstrated by the radiopaque Ca(OH)₂. The CBCT imaging guides treatment in a way that complements the microscope. The access can be precisely extended if needed to address the additional anatomy. The access extension is minimized, as the direction and distance is known, guided from the imaging study.

Regarding the concerns with conservative canal preparation and the clinician's need to “cleanse and shape the canal properly,” it is imperative to remember that these are the clinician's needs, not the tooth's needs. The amount of cleaning and shaping (if any) required for radiographic evidence of resolution of apical periodontitis is simply not known a priori. The CBCT often allows rapid 3- to 4-month semi-quantitative assessment of periapical radiopacity change to infer that the biological requirements have been met. Proper utilization of the CBCT addresses these concerns and is a requirement in a state-of-the-art endodontic practice.

The New Language of the PCD
The pulp chamber and root canal orifice projections appear unique in every clinical scenario. Pulp chamber morphology,
when reviewed in 3 dimensions, can be described to have height, width, and depth that ultimately forms a platform shape utilized for retention in subsequent restorative procedures (Figures 5 and 6). Two of these dimensions are visible on periapical (PA) or bite-wing (BW) imaging and may be used to plan or guide treatment. Platform width is the line joining between the mesial and distal root canal system, platform depth is the line joining between buccal and lingual root canal systems, and chamber height is the distance between the furcation floor and roof of the pulp chamber. Access is planned using a directed approach taking these relationships into account (Figure 7). With a very ample platform width, an individualized access approach can be utilized for a specific canal with the system (Figure 7, rightmost). For the interested reader, Best Practices 16 has more in-depth discussions on these topics by some of the co-authors of this paper (MT, PN, SB).

To practice endodontics at the highest level, a CBCT and microscope are required. Figures 8 to 10 show what can be done with image-guided principles and these crucial pieces of technology. However, as the cases from my 2 restorative colleagues clearly demonstrate in Figure 11, these image-guided principles can be applied in general practice with PA projection or BW radiography. In both cases, the entire access is confined to the mesial half of the tooth.

Figure 9. IGT: Endodontist Dr. Charles Maupin (Lubbock, Tex) uses imaging and clinical assessment to plan the access to the canals. Palatal decay is removed, gaining access to both the palatal canal—and through the distal-angle orifice-directed approach—the MB2 canal as well (shown obturated with gutta-percha). A separate entrance allowed access to the MB and DB canals.

Figure 10. IGT: Here we use pre-op PA imaging to identify in the pericervical anatomy of a tooth with a very wide platform with minimal canal convergence similar to Figure 6 (rightmost). We plan to create a dual access retaining a truss. Clinical closeups show the MB (top) and ML canal orifices. Shaping to minimal size, Ca(OH)₂ placed, and the CBCT guides the search for any additional anatomy for which there was none. Post-op with final shapes with SS White VTaper 2 and follow-up.
Image-Guided Endodontics: The Role of the Endodontic Triad

Note the exceptionally narrow necks to the pulp chambers, and the subtle extension at the cavosurface alone access to the MB system in the maxillary molar. The distal chamber and horns are not unroofed. This simply removes healthy tooth structure and damages the tooth. The teeth are restored with composite resin. Notable in both restorative practices is that neither tooth received an indirect restoration. Both of these restorative clinicians are well aware of what works and of the damage created by drilling on teeth and removal of sound tooth structure, a lesson endodontists and endodontics would do well to learn. As Dr. John Kois has said: “Creating more conservative access openings can reduce the risk of tooth loss related to weakened tooth structure. Significant problems are more related to the loss of tooth structure more than the endodontic procedures themselves.” There is academic evidence to support conservative access openings as well.

CLOSING COMMENTS

We would like to summarize this article for both our restorative and endodontic colleagues. My long-time friend, colleague, practice partner, and restorative dentist-turned-endodontist, Dr. Glen Doyon of Scottsdale, Ariz, said it best:

“It’s harder for the endodontist to accept controversy over accepted dogma. After practicing general dentistry for 20 years before specializing in endodontics, I come from a different place than the straight-up endodontist. It’s easier for general dentists to really understand and get this idea of minimally invasive endodontics because they see how these endodontic legacy concepts have affected long-term tooth retention. Endodontists don’t see their failures and the general dentists do.

“One of the problems of the legacy endodontic culture is that they don’t really know what works and what does not work long-term…I’m talking more than 4 years, for the patients. The general dentists see and have the follow-ups because the patients come back to their office. People come back to the general dentist all the time to have their teeth cleaned, so the general dentists see what goes wrong. Endodontists don’t really know what works and what doesn’t over a long period of time. Endodontists think lack of evidence of failure is success. If you ask them, they think their cases are 95% successful. They just don’t know.”

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Image-Guided Endodontics: The Role of the Endodontic Triad

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1. Endodontic treatment protocols have been based on the tooth type, not specifically tailored, nor executed in appreciation of the morphologic and anatomic uniqueness routinely encountered.
   a. True   b. False

2. Precision medicine refers to the tailoring of medical treatment to the scientifically averaged characteristics of all patients.
   a. True   b. False

3. Traditional endodontic treatment has been convenience-driven and endodontic-centric, primarily focused on operator needs, and has been decoupled from the restorative needs and tooth needs.
   a. True   b. False

4. Smaller access (openings) might hinder the clinician’s ability to locate clinically relevant anatomy, and has been a primary objection to the minimally invasive strategy.
   a. True   b. False

5. The CBCT imaging guides treatment in a way that complements the microscope; access can be precisely extended if needed to address the additional anatomy.
   a. True   b. False

6. Regarding the concerns with conservative canal preparation and clinician’s need to “cleanse and shape the canal properly,” it is imperative to remember that these are the tooth’s needs.
   a. True   b. False

7. To practice endodontics at the highest level (possible; and as limited by current technology) only a microscope is needed.
   a. True   b. False

8. As Dr. John Kois has said: “Significant problems are more related to the loss of tooth structure more than the endodontic procedures themselves.”
   a. True   b. False
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