

Endodontic Treatment Planning in the Fourth Dimension

L. Stephen Buchanan¹

“...Time loves a hero, but only time will tell if he’s real...”
— Little Feat

And so it is with endodontic treatment planning. This article discusses treatment-planning rules that will help your endodontic therapy stand the test of time, finishing with a report from the digital frontier about how 3-dimensional (3-D) digital imaging is revolutionizing treatment planning as well as the accomplishment of exceptional dentistry. It all begins with first order issues.

First Order Issues

My father, a retired control systems engineer (missile guidance), taught me that the most important thing to do at the beginning of any creative pursuit is to search out and determine the “first order issues.” What are first order issues? Here’s an example: if you were designing a suite of software that would later run the world of PC computers, you would want to be certain that you leave enough character spaces in the date field so that the software could survive Y2K. I know. Not that easy, but it is really important.

Dental examples of respect for first order issues would be: 1. making sure that you are not planning to retreat a root-fractured tooth, or the other extreme 2. making sure that you are not replacing a tooth with an implant when a

simple endodontic procedure could be done with a high expectation of success (Figures 1a and 1b).

So what are the first order priorities in treatment planning for endodontics? I would have to say that it boils down to 4 serial requirements:

- Determine the prognosis.
- List possible courses of treatment.



Figure 1a: Maxillary molar with failing root canal treatment. The dentist who originally treated the root canal system (only the palatal canal!), only after the patient complained of continuing symptoms, offered to extract the tooth and replace it with an implant.



Figure 1b: Post-op result after single-visit retreatment. The patient’s symptoms were immediately relieved, possibly by adding the remaining 3 canals to the endodontic treatment plan.

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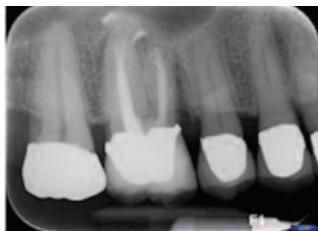


Figure 2: Maxillary molar with an infected vertical root fracture of the mesiobuccal root. The root canal therapy (RCT) was successful apically, but the over-enlargement caused a coronal failure of structural integrity.

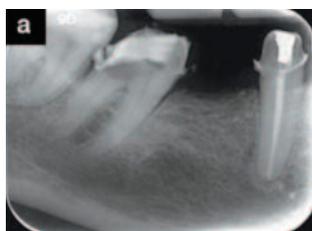


Figure 3a: Mandibular molar with deep distal decay nearly hemisecting the distal root. The structural damage was extensive.

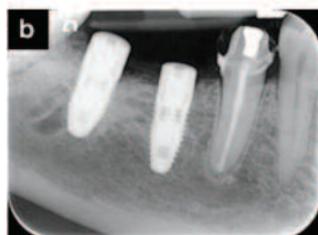


Figure 3b: Recall x-ray 4 months after immediate implant replacement of the molar. This treatment plan, with the second implant in the edentulous space, has a much better long-term prognosis than RCT and restoration would have provided.



Figure 4a: Maxillary central incisor broken off at the gumline. The challenge of creating an adequate ferrule around the remaining root structure with an ideal aesthetic result suggested replacement with an immediate implant.

- Choose the best treatment.
- Plan the procedure.

Regardless of how far our procedural technology advances in the future, these 4 issues will always beg an answer before any cutting occurs.

Determine the Prognosis

Careful assessment of the overall damage that a tooth has endured—and a wise determination of its prognosis—is a prerequisite to successful treatment planning. This is not an article about diagnosis but, suffice it to say, exceptional endodontic treatment after an erroneous diagnosis is not going to benefit the patient. Likewise, an exceptional endodontic procedure, done on a tooth that falls apart after treatment, will not be appreciated.

Discovery of the full extent of pulpal, periodontal, or

combined disease conditions requires definitive pulp testing (with sustained sources of thermal stimulus), careful periodontal probings, and the best radiographic imaging you can get. Then, after considering all of the relevant data, a very well-informed prediction of its potential longevity is made.

The first order conditions to consider in prognosis determination (listed in order of importance) are: 1. structural damage (Figures 2 to 4b), 2. periodontal damage (Figures 5a and 5b), and 3. endodontic damage (Figure 6).

Structural and periodontal conditions will always trump the endodontic condition when considering whether to save or extract a tooth. A beautiful endodontic retreatment will not keep a structurally compromised tooth from coming apart in the near future, nor will it heal periodontal lesions that are not of an endodontic origin.



Figure 4b. Postoperative x-ray showing immediate implant replacement.

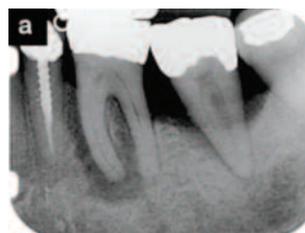


Figure 5a. First and second molars with endodontic and periodontal disease.

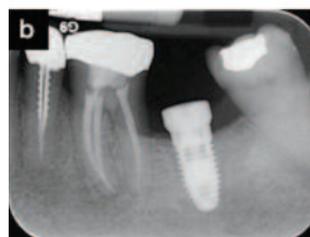


Figure 5b: Two-year-recall exam showing successful RCT of the first molar and replacement of the second molar with an implant and prosthesis.



Figure 6: Maxillary lateral incisor with a hedstrom file separated near the end of the canal and an osseous lesion at the root apex. This could be re-treated conventionally after removal of the crown, the core, the post, and the file segment, or – if the post and core appear to be intact – re-treat the canal from a retrograde approach. Much less cost, less treatment time, and a certain result.

Any tooth with a root fracture extending (even one mm) into the soft-tissue attachment at the cemento-enamel junction should be extracted. No endodontic or restorative treatment that I have ever seen can prevent the certain demise of a root-fractured tooth. Be definitive with these loser teeth.

When periodontal damage has occurred, the trend of the disease state is informative as to the prognosis for arresting the disease and repairing damage in the supporting tissues around a tooth. Also important is whether the periodontal defect is specific to that tooth, or part of a generalized periodontal condition. An isolated periodontal lesion, coupled with a suspicious or definitely bad pulp test result, indicates an endo/perio situation that has a fair to good prognosis with the right treatment.^{1,2}

Damage from previous endodontic treatment is common, and most of the mishaps that have occurred in the apical third of roots are repairable without apical surgery.³ When needed, surgical resection of the apical half of a root will not significantly reduce the longevity of that tooth.⁴ Conversely, overcutting the access cavity and the coronal one half of the root can doom a tooth to structural failure. Posts never strengthen roots after endodontic treatment, and neither will composite bonding; and cut dentin never returns.^{5,6}

Conversely, when access cavities are cut conservatively, when coronal enlargement of canals is limited and the restorative work is well done, endodontic treatment nearly always offers an excellent long-term structural prognosis.

Prognosis determination informs but does not decide the treatment plan; for example, it may be preferable to retreat a



Figure 7a: Conventional preoperative radiograph showing obscure root structure.



Figure 7b: Computed tomography (CT) view showing buccal canals merging apically with a 3 mm long accessory canal diverging from the point of confluence.

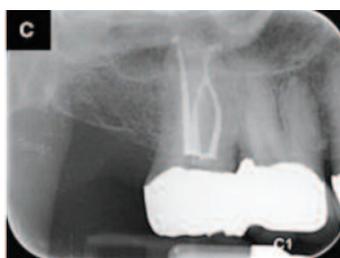


Figure 7c: Conventional postoperative radiograph showing root canal anatomy shaped and obturated just as seen preoperatively in the CT image.

tooth with a guarded long-term prognosis if the patient is elderly, rather than subject that patient to extraction and implant placement, or extraction without replacement. Likewise, for our younger patients we must recommend and execute treatment plans that have the longest attendant prognoses.

List Possible Courses of Treatment

So, if we have successfully assessed the disease state and our forecast of the current prognosis would indicate saving the tooth, the choices are the following:

1. **Do nothing.** This is not an option for necrotic teeth; infected teeth need root canal treatment (RCT) or extraction.
2. **Conventional RCT.** Well-done RCT works as often as implants. It can be done in a single visit, and the tooth is ready for a new crown in 2 weeks.
3. **Surgical RCT.** Calcified canals are always found from a retrograde approach, and sometimes a critical abutment should not be disturbed by cutting an access cavity through it. The whole canal must be treated from the apical approach.
4. **Conventional retreatment.** This is the only choice when coronal leakage has occurred and is the automatic treatment of choice for missed canals and irrigation failures. It is difficult when apical damage has occurred.
5. **Surgical retreatment.** This is still better than an implant if the structure and periodontal findings are good. It is the best option when coronal structures are tight and apical damage has occurred.
6. **Conventional and surgical retreatment.** This is for those retreatment cases that absolutely must work. Andreason's research showed nearly 100% success when orthograde (from both ends) treatment was done on teeth with failed RCT.

These choices should be explained to the patient in terms of operative and postoperative discomfort, the expected treatment result, the long-term prognosis after, and the cost of treatment.

Choose the Best Treatment

Recommending which treatment course to pursue is usually simple when looking at single teeth. The tooth may be totally unsalvageable—root fracture, for example—and the only treatment that would be considered is extraction. In this case, there are decisions to be made about restoring function and aesthetics after the tooth is removed, but none regarding the tooth itself.

A more difficult call is about a tooth with a little bit of every type of problem. For example: a Class I furcation; three quarters of the coronal structure is missing; and the previous root canal was not done well. Some of the considerations in gray-area cases like this would be: Is the



Figure 8a: Maxillary second molar with an apparent endo/perio lesion.

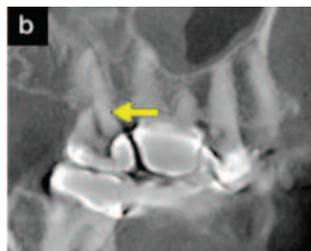


Figure 8b: CT slice showing an osseous radiolucency wrapping from the distal aspect of the root into the distal furcation. No periapical lesions seen at any of the root apices. Pulp testing confirmed the CT imaging suggesting a periodontal lesion without an endodontic component.



Figure 9a: Conventional preoperative x-ray showing no obvious periradicular pathosis.

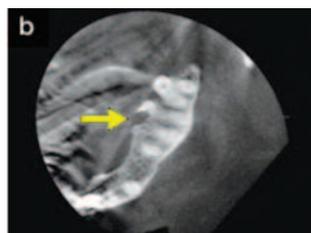


Figure 9b: CT view showing the palatal root nearly resected by a large external resorptive defect.

perio defect isolated or generalized? Was the coronal third of the canals overenlarged? Has the root been damaged apically during previous treatment? Will both conventional and surgical retreatment be necessary? Would an implant replacement be easy or hard? What is the financial ability of the patient to fund more expensive treatment choices if indicated?

If the assessments of the disease state, its extent, and the prognoses of each possible treatment are accurately and adequately explained to patients, then they can make a decision that is best for them.

Perhaps the first order issue for dentists recommending a course of treatment is about bias. There are several kinds of bias that intrude on clinical judgments. Self-interested bias is easy to see and to avoid in most situations. Unconscious bias can be harder to avoid; for example, the tendency of clinicians to limit their recommended treatment options to procedures they feel comfortable

doing themselves.

After consideration of all factors, I would recommend the same course of treatment that I would want myself or that I would want another dentist to recommend to a family member.

Plan the Procedure

Many of us consider treatment planning to be completed after the choice of treatment has been made. I disagree with this concept because without a procedural plan in place before difficult cases are begun, endodontic therapy can quickly go awry. The best treatment plan cannot overcome mediocre procedural execution. So how do we better plan our procedures?

I would recommend that all clinicians and assisting team members read Dr. Atul Gawande's book entitled *The Checklist Manifesto – How To Get Things Right* (Metropolitan Books, 2009). Also, I recommend his

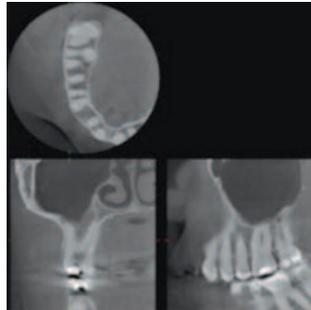


Figure 10: Axial CT section showing, with 100% certainty, that there is no MB2 canal in this upper molar. Also seen is the normally hidden 90° buccal curvature of the DB canal.

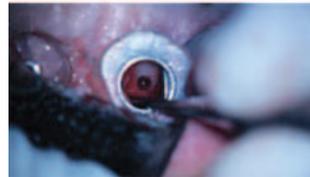


Figure 11a: Initial 2 mm drill hole seen through the guide ring of a prototype drill guide for CT-guided endodontic surgery procedure. (Note accuracy attained.)



Figure 11b: Photograph showing a perfectly apicsected root-end after using the CT-based appliance to guide each of the cutting drills.

other books Better: *A Surgeon's Notes on Performance and Complications: A Surgeon's Notes on an Imperfect Science*. This gentleman is an excellent journalist, a surgeon on staff at Harvard Medical and Harvard Public Health Schools, and the director of the World Health Organization's "Safe Surgery Saves Lives" program. For years, he has pursued a campaign to improve surgical and all health-delivery outcomes through research into best practices, feeding the outcomes data back to operating rooms around the world.

One of the most powerful epiphanies he had was in realizing that many fewer errors are made in the airline industry as compared to medicine and that this is literally because they live and die by checklists.

Dr. Gawande has begun enlisting hospitals around the world in his studies related to checklists for quality control in healthcare. Those who have participated have seen remarkable improvements in results, especially in complex operations when most of the

operating team and surgeons are unknown to each other. At the end of the day, Dr. Gawande is improving procedural results by documenting them with preoperative, midprocedure, and postoperative list checks, thereby nipping small and large errors in the bud. Furthermore, this process creates a very effective structure on the backend that encourages iterative improvements of those procedures.

First order issues for procedural planning are the following:

1. **Know your skills.** Never stop practicing or training up.
2. **Know your patient.** Premedicate the patient if needed.
3. **Know the patient's anatomy and the full extent of the disease.**
4. **Plan every single part of the procedure.** Definitely have a Plan B.
5. **Have all necessary instruments, materials, and supplies with backups.**
6. **Have the right team members in the right positions, with the right checklists.**

3-Dimensional Computed Tomography Imaging

Cone beam computed tomography (CBCT) imaging has changed everything in dentistry. Not a great number of clinicians understand this yet, but it will not be very long before most do. When dentists who have easy access to a CBCT machine consider the very low amounts of absorbed radiation that some of these machines project⁷ as well as the quality of the volumetric data captured,⁸ treatment planning without it is similar to the experience of doing root canal therapy without a microscope.

The dimensional accuracy of CBCT machines is proven,^{9,10} and the resolutions of some of the machines approach 50 μm , making it possible for lateral canals to be seen preoperatively¹¹ and it has somewhat delivered on one of my childhood fantasies of having x-ray vision. Even if you thought you were Superman when you looked at conventional dental x-rays, having volumetric x-ray imaging is like being Superman in a world without Kryptonite.

The 3-D x-ray imaging allows clinicians to know everything about a given tooth's anatomy and the fullest extent of the disease state before any invasive procedures are done (To see a video of diagnosis and treatment planning with CBCT imaging visit endobuchanan.com). Let's look at several examples of anatomic challenges that are normally hidden on 2-dimensional dental x-rays but are easily seen with CT imaging (Figures 7a to 7c). Because of the contributions of CBCT imaging, prognosis determination for teeth with failing endodontic treatment is now more definitive—and just being able to weed out most of the loser teeth before cutting an exploratory access is a major bonus for dentists and patients alike.

Let's also take a look at some clinical comparisons of conventional and CBCT imaging for assessment of disease states (Figures 8a to 9b).

Digital Does It Better

For those clinicians who have had a CBCT machine in their office for more than a year, the advantages of 3-D volumetric x-ray imaging is incontrovertible. Competitively, as an endodontic specialist, it's an unfair advantage.

Even beyond the diagnostic benefits of CBCT imaging, the advantage of 3-D imaging to the clinician actually doing the procedure is huge (Figure 10). We are currently able to set up a drill path to pass, in the 3-D virtual anatomic computer space of your patient's tooth, exactly through each root apex, and then have a drill guide made to carry that computer plan directly into the patient's

mouth—kind of like robotic surgery, except we still get to hang on to the handpiece. Now you are talking about some very fun, very effective outcomes. Faster, better, and safer—that is music to a lazy perfectionist's ears.

This is not pie-in-the-sky vaporware. The technology now exists to capture and reconstruct our patients' dental anatomy and disease to a .001 mm resolution. The software for surgical treatment planning in voxel space has been used for years in implant surgery and is currently under development for endodontic surgery. And let me tell you, it is a relaxed and very cool experience to secure a CAD/CAM stereolithography-generated drill guide precisely onto your patient's teeth, and complete all of the drilling and milling for a given procedure in a minute or 2 with remarkable precision (Figures 11a and 11b).

In other words, we are way beyond the early-adopter phase with this technology. When you look at the convergence of the tools mentioned above with digital impression scanning, and CAD/CAM milling machines, the future is clear. While it may take a generational change of dentists to fully understand the advantages of these new digital tools, clinicians like myself who have reveled in The New, New Thing since the day they graduated, will chase this 3-D imaging and digital treatment planning protocol like a dog chasing a cat.

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