

Strategies for Biocompatible Endodontics

And a technique manual for using calcium oxide to fill root canals

We Still Need Root Canal Treatment

Despite the fact that there are serious objections to the use of root canal treatment in dentistry, due to the persistence of microbes in the dentinal tubules, the inaccessible microscopic spaces in a root, the fact remains that it is an ingrained part of our professional culture. It was easy to convert to mercury-free restorative dentistry once good alternatives became available, but the only alternative to endodontics is extraction, and our patients have been trained by the greater society to expect to keep their teeth. Even highly aware and health conscious patients can become subject to the conundrum of whether to lose a tooth or keep it at the price of a root canal treatment.

A discussion of the problem of long term toxicity emanating from root treated teeth is presented in the video, "[Rooted](#)," by Dr. Robert Gammal. Also see the book, [Root Canal Coverup](#), by Dr. George Meinig, available on Amazon and other online sources.

A perfect example of the current state of confusion among health conscious consumers trying to do the right thing for themselves is illustrated in figure 1. This patient entered the care of a "holistic" dentist, who convinced him that root canal treated teeth were unhealthy. Therefore, tooth #12 (24) with its old root treatment, had to go. The tooth was extracted, the extraction site handled according to the latest anti-NICO protocol, and a porcelain fused to gold bridge was placed. He later moved to another city and sought another holistic dentist, because his bridge was bothering him. When the new dentist took a radiograph, it was apparent that tooth #13 (25) had now developed a



periapical radiolucency, and needed a root canal treatment, or the new bridge would have to go too. The patient replied, "Forget it, I just paid \$3000 for that bridge!" OK, let's do the root canal treatment, says the dentist. "Uh-uh, root canals are no good for you," responded the patient, and he went away untreated, only to return a year later with a serious, painful abscess.

Figure 1

The possible responses a dentist can make when faced with non-vital teeth ranges from the typical, uncritical trust and dependence on root canal treatment, all the way to the “100 percenters” total rejection of it. Unfortunately, our determination to avoid the possible toxicity of root-treated teeth clashes with the complexity of clinical situations, and the science, while suggestive, is limited. We don't know how to tell which tooth in which patient will present a toxic challenge that exceeds that person's physiological ability to deal with it.

We still need endodontics. No dentist can prevent the consequences of a patient's caries history and the restorative dentistry that follows, as the example above illustrates. In some cases, it will be acceptable to extract a tooth that would otherwise be a root canal candidate. In many other cases, it will not be acceptable to the patient to lose the tooth, and we must be prepared to treat the root canal.

Can there be an endodontic technique that minimizes the toxicity that develops in a root treated tooth? Can there be a middle ground between uncritical trust of root canal treatment and extracting everything? Can there be a treatment for the root canal and the dentin tubules as well? The IAOMT has some strategies to add to the discussion, methods that may improve the outcome. It takes a bit of knowledge and technique. Not enough information is available to allow us to be certain whether these methods can alleviate the problem of long term toxicity in root canals, but we offer these options for your consideration.

Everything to Kill Microbes

The standard technique in endodontic therapy is to clean, shape, disinfect and fill the main channel root canals, with no attempt made to reach into and disinfect the microscopic spaces. It's well established that canal irrigants and disinfectants penetrate only the first 100 microns of the dentinal tubules.¹ This approach has been very successful at getting rid of overt pain and infection, but inevitably leaves bacteria living in the dentinal tubules and other inaccessible places. Their metabolic waste products, anaerobic toxins which can be very potent, leach slowly out of the tooth into the body. If we are to continue to treat root canals, we must accept a new responsibility. Disinfecting the tubules must become the standard.

There actually are a variety of techniques that are well supported in the literature that are known to project germ-killing disinfection into those microscopic spaces of a root. Some that we can consider are the inter-appointment treatment dressing, ozone therapy, laser therapy, and final filling with calcium oxide (Endocal-10). Can there ever be perfect disinfection? Certainly not, because there is no regeneration of the pulp, with its blood supply, fluid flow, and immune potency. It will always be an asymptotic

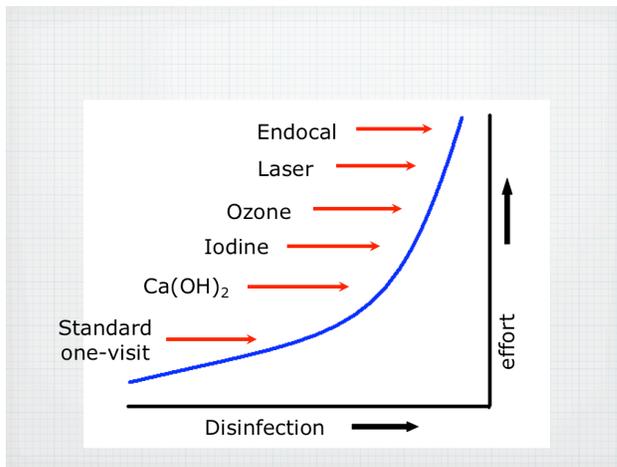


Figure 2-

process, one in which, with more effort, by adding disinfecting procedures, we can approach, but never really reach the goal. (figure 2) Somewhere on the graph of effort vs. disinfection is a vertical line that represents the patient's threshold for tolerating a non-vital tooth. It may vary with each patient; it may vary with each tooth. What we are truly lacking is a verifiable method for evaluating that threshold, and keeping track of it over time.

Treatment dressings between appointments are a classic method for disinfecting the roots of non-vital cases, and the agents used are quite diffusive, typically able to penetrate dentin tubules. Toxic phenols have been used traditionally, although they can be detected systemically within minutes of their application in a tooth.² Calcium hydroxide, a relatively efficient disinfectant, is far more biocompatible, and known to diffuse through dentin as well. The effectiveness of calcium hydroxide is greatly enhanced when it is mixed with chlorhexidine or iodine.³ Iodine, of course, has the advantage of being not only biocompatible, but nutritional, in addition to its germ-killing properties. An easy treatment dressing can be made by mixing dry calcium hydroxide powder (SultanHealthcare.com) with either povidone iodine, or I-KI solution. There is no hard and fast rule about how long to leave it in the tooth between appointments.

Ozone therapy has emerged as a very useful all purpose anti-infective therapy.⁴ Canals can be irrigated during treatment with ozone saturated water instead of sodium hypochlorite. It is as effective as a disinfectant, without the attendant cytotoxicity. Whether it has the same digestive capacity for organic material is not known. Oxygen-ozone gas can be used to fumigate canals once they have been cleaned and shaped. The ozone, being very highly soluble, will dissolve into the moist tubules. Oxygen-ozone gas can be used to perfuse the peri-radicular bone with a trephine device such as the X-tip, to provide disinfection of the medullary tissues, and promotion of healing. Training in dental ozone therapy is available from an [IAOMT affiliate](#).

Laser therapy is gaining increasing acceptance in dentistry, not least in endodontics. In particular, the Waterlase (Biolase, Irvine, CA) has long, flexible fiber tips that are polished in such a way that the energy is directed out in a radial pattern. When they are placed in the root canal, the laser light shines right into the tubules, which act as wave guides, conducting the pulsed energy through their length. With the right amount of time and the right energy settings, effective disinfection of dentinal tubules can be documented.^{5 6}

The French Paste

Calcium oxide, or quicklime, has been used as a disinfectant since time immemorial. Its use in modern endodontics dates back to France in the mid 1960's and the publication of Pierre Bernard's work, Therapie Ocalexique.⁷ Bernard proposed that CaO would diffuse through the hidden, microscopic spaces of the root canal system, providing continuous disinfection throughout the structure of the dentin, and ultimately obturation, by hardening in place; in other words, a treatment for both the root canal and the dentin tubules. His work was promoted and improved upon by Pierre Fohr, and Pierre Morin, who introduced "heavy" CaO, a much denser crystalline form that delivers up to three times as much calcium per volume as the original quicklime formula. The "three Pierres" and others including Cohen-Scali, began an era of interest in ocalexique root canal therapy in Europe, which has waned severely in recent years in the face of technical improvements (and marketing pressure!) from American gutta percha methods. The ocalexique technique was brought to North America by Pierre Donnedieu, DDS, of Montreal in 1979, and promoted by IAOMT member Guy Duquet, DDS.

Commercially, CaO root canal material was manufactured and marketed for a long time by Spad Laboratories in France, under the name "Biocalex 6/9." Biocalex was discontinued in 2001, shortly after Spad was acquired by Dentsply. It is now manufactured by Albuca Laboratories, of Montreal, and sold under the name "Endocal-10."

The first question dentists ask about this alternative technique is, "How long do they last?" There has only been one prospective follow-up study conducted by some IAOMT members, and available [here](#). It showed three-year clinical success rates that were indistinguishable from the literature on conventional techniques. Those dentists who have stuck with CaO root treatment over the years have experienced great clinical success, at least at the anecdotal level. None of the detractors' dire predictions have come true – roots don't break from expansion of the material, cases don't "wash out" and get reinfected, and there is nothing in our experience to indicate that it is in any way inferior to standard root canal therapy (figure 3).

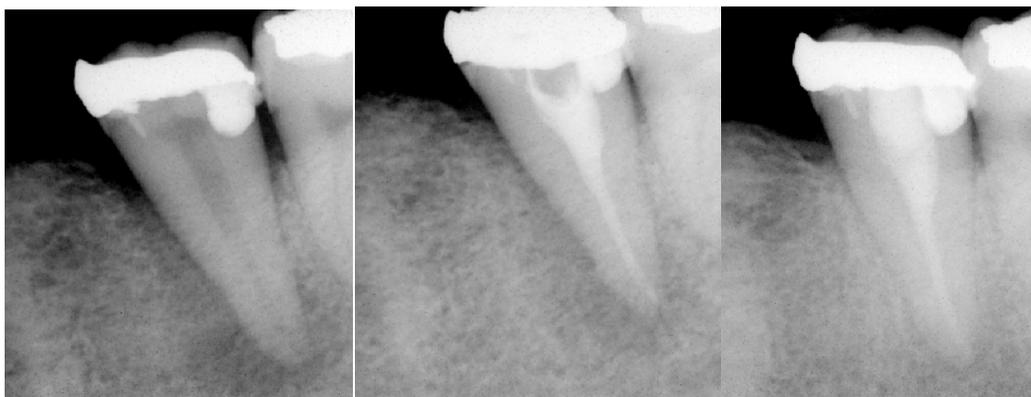
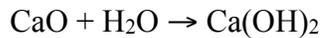


Figure 3 – A combined endo–perio lesion resolves after CaO root canal treatment.

Why Calcium Oxide?

Calcium Oxide as a root canal filling material represents an attempt to merge the well known disinfecting properties of calcium hydroxide with a hard setting, obturating material – in other words to make the calcium hydroxide effect permanent. Dentists have always used lime in the form of calcium hydroxide (Ca(OH)_2) as a disinfectant and stimulator of tissue regeneration. It is slightly soluble in water, and dissociates to form a powerfully alkaline solution, at pH 10 –11, which is inhospitable to germs but seems to have a stimulatory effect on dentin and bone cells. Unfortunately, it never sets hard, and does wash away in time from the root canal, leaving the tooth susceptible to reinfection.

Calcium oxide (CaO), on the other hand undergoes two reactions that make it much better suited as a root canal filler. First of all, it reacts with water, to form Ca(OH)_2 , yielding all its beneficial properties:



Secondly, it reacts with carbon dioxide ambient in the extracellular environment to form calcium carbonate, also known as limestone:

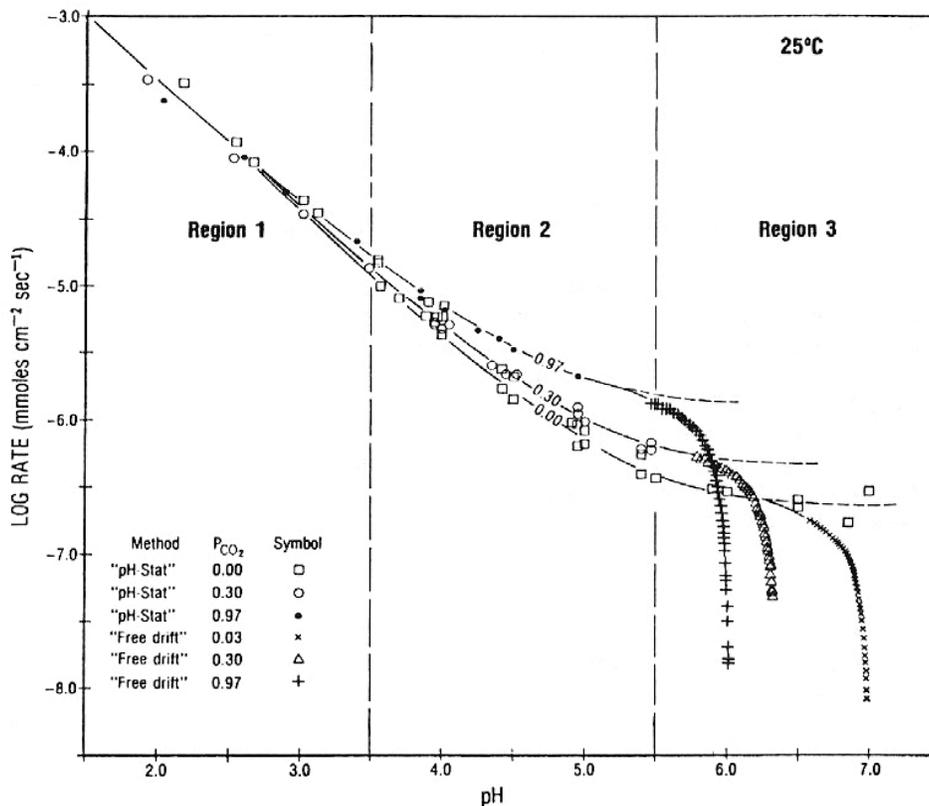
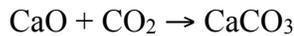


Figure 4 – Solubility curves for CaCO_3 , depending upon pH and p_{CO_2} , from Plummer, et al, (1978).

Calcium carbonate will form and remain insoluble only as long as the milieu is alkaline (figure 4). In an infected root canal, where the environment is made acidic by bacterial metabolic activity, CaO will generate Ca(OH)_2 , which then buffers and disinfects. When the infection comes under control and the fluids return to physiological pH, the reaction of CaO turns to generation of calcium carbonate, and the material hardens in place. It's a *self-regulating system*, a material that is both an active disinfectant and an obturator, as required by the surrounding conditions. If the periapical infection reasserts itself and again produces acid, the previously hardened calcium carbonate will re-dissolve, yielding more Ca(OH)_2 to fight the infection.

Calcium oxide is strongly hygroscopic – it attracts water, and will expand through a water layer. This gives it the ability to actively diffuse through the microscopic spaces of a tooth, the tiny fins, isthmuses, lateral canals, and dentinal tubules. Minana⁸ et. al showed that CaO, placed in the root canal of extracted teeth, can diffuse completely through the dentin and raise the pH at the cemental surface as effectively as Ca(OH)_2 . Guigand, et. al,^{9 10} demonstrated that calcium from CaO penetrates into dentin tubules further than that from Ca(OH)_2 , and that CaO dissolves organic matter such as predentin and smear layer more effectively than Ca(OH)_2 . The hygroscopic nature of CaO has also given rise to one of the most serious objections to its use, namely the fear that pressure developed by hygroscopic expansion will fracture roots. This misapprehension derives from an unfortunate translation from the French, and if the original translator had used the word “penetrating” instead of “expansive,” we wouldn't have had to labor under this misunderstanding. In clinical practice, CaO root treatments do not break roots. Treated roots sometimes break, it's a fact of life in endodontics, but clinical experience shows that the CaO treatments do not produce excess fractures.

Calcium oxide root treatment is not always as efficient or convenient a method as the standard gutta percha filling technique. It does not lend itself to single visit endo, because the hardened set of the material has to be checked at a subsequent appointment before restoration can proceed. The setting process is not a two-part chemical reaction, like ZOE or resin-based sealers. It sets by a biologically mediated interaction with its environment. Usually it sets on the first application, but not all the time, and much more reliably when used after a period of calcium hydroxide treatment dressing. We use it despite the inconvenience because it is an attempt to more fully disinfect the treated tooth. If we can get an active disinfection of the dentinal tubules, we are more likely to avoid the kind of long term toxicity that develops in the tubules from anaerobic bacterial waste products. We have confidence that the CaO penetrates the tubules, disinfects them, obturates them, and stays there more effectively than anything else we can use. We hope, subject to future research, that we are really having the effect we desire – treating the dentin tubules and producing a less toxic root canal!

Technique Manual for CaO Root Treatment

1. Case selection.

There do not appear to be any conditions that can be treated endodontically that can't be treated with CaO. The same problems that increase the failure rate of any root canal treatment will compromise CaO treatments as well – broken instruments, incompletely prepared canals, long standing infection, etc. There have been suggestions and claims that because CaO is penetrating and actively disinfecting, it can succeed in reversing infection in cases where the canals are not fully accessible. That may be true, but there's no research to back up the statement.

Something should be said for evaluating a patient's overall health status, to evaluate the relative risk of root canal treatment for that individual. Should a person with chronic illness, immune system challenges, or other debilities be expected to tolerate root treated teeth? This is currently a matter of art, not science. Whose choice will it ultimately be to keep or lose an affected tooth?

2. Informed consent.

In the United States, where fully informed consent is the rule, the dentist must inform the patient that the CaO root canal technique is not the prevailing standard, that it is an "alternative" method, and that if the patient prefers, he or she can receive the standard treatment instead, either in your office or by referral.

Legally, Biocalex and Endocal have section 510(k) "premarket notification" approval from the FDA, allowing them to be sold for use by dentists in the USA. No state dental board has ruled as to whether CaO root treatment is within the standard of care or not. In Canada, the Quebec Order of Dentists has found it to be within the standard of care.

3. Canal preparation.

Because the CaO material is a paste filling, the goal of instrumentation is to allow a Lentulo spiral to reach the apex without binding or obstruction. You need a wide preparation to do this, like the Schilder prep for vertical condensation, or a wide conical prep to the apex. The modern machine driven rotary techniques with NiTi files make this goal so much easier to attain than hand files, it's like night and day. Tulsa ProFiles, Files of Greater Taper, Lightspeed, Twisted Files, are some of the brand names. It's well worth learning how to use one of these systems.

The location of the apex should be within 1 millimeter of the radiographic apex, or the actual full length measurement if you use an electronic apex locator.

The earlier French authors preferred very little preparation, to preserve as much tooth

structure as possible. They felt that the ocalexique technique was essentially chemical, not mechanical.

An interesting series of experiments at the University of Texas argues in favor of the wide prep.^{11 12} When the roots of extracted teeth were filled with Ca(OH)_2 pastes, such as Pulpdent® or Ca(OH)_2 powder suspended in water, the pH of the entire thickness of the dentin, as measured at the cemental surface, was quickly rendered alkaline. But when the roots were filled by condensing gutta percha into a Ca(OH)_2 containing sealer, such as Sealapex® (Kerr), thereby reducing the amount of paste left inside the root, there was no such effect, and the root surface pH did not change. This was later repeated using CaO, with the same result.¹³ The implication is that if raising the pH is related to disinfection, and you want to alkalinize all the way through the dentin structure of a tooth, you need a bigger reservoir of calcium material. A wide root preparation makes this possible.

4. **Irrigation.**

There are many opinions on irrigants – for and against hypochlorite, especially. There is no conflict between the CaO root filling technique and any irrigation scheme you like, with one important exception: you must limit the use of EDTA canal irrigants.

Any EDTA remaining in the canal will sequester the calcium, and poison the calcium-based root filling. It will absolutely prevent CaO from setting. You must rinse it out thoroughly. Rinse with sterile water and dry with paper points two or three times after using EDTA. There is an interesting observation about EDTA made by some IAOMT members. It seems that those who use EDTA for the longest time during instrumentation have the most trouble with CaO failing to set, while those who use it the least report only rare problems with setting. Perhaps it diffuses into the tubules, forming a reservoir that leaches back into the canal later on. On that basis we recommend against using RC Prep® or Glyde® during instrumentation.

5. **Go right to CaO, or use a treatment dressing?**

There is a debate going on in endodontics right now over the single visit treatment that has been advocated over the last decade. Some authors are advocating a treatment dressing of Ca(OH)_2 for a week or two after the instrumentation appointment, especially in non-vital cases, and obturation on a second visit.

We can use CaO as both a treatment dressing and as an obturant, since it either generates Ca(OH)_2 or sets hard as CaCO_3 , depending upon the surrounding conditions. Instances of weeping or bleeding from the canal apex, that one would normally treat with a Ca(OH)_2 dressing, can be equally treated with CaO. But the

evidence is that alkaline calcium by itself is a good but not perfect disinfectant, and there will be instances in which it may be advisable to use a treatment dressing to get an infection under better control.

6. Filling the canals with CaO.

Mix the CaO material (Endocal®) according to manufacturer's directions, to the familiar sour cream consistency. The canals are filled using a Lentulo spiral. In order to prevent trapping of air bubbles, start with a thin, number 1 (or ISO 25) spiral, and load it only to its own diameter. Don't glob the paste on it, to avoid trapping air. Slide it down to the apex and rotate at a medium-slow speed. Keep it there for ten whole seconds, because it will progressively beat any air pockets out of the fill. Withdraw slowly while spinning. Repeat this step in each canal two or three times, and then again with a larger diameter Lentulo. Apply only an amount that will fit within the diameter of the spiral, and let it spin to beat out any trapped air. It is inconvenient to keep repeating this way in, say, the mesio-buccal canals of upper second molars, but the results are worth it in terms of density of the fill. You can appreciate the need for a wide canal prep when you think of a Lentulo spinning all the way to the apex. If it binds, it's broken!

Temporize with a non-eugenol temporary filling.

Endocal, like Biocal before it, is not well suited as a sealer for gutta percha. It is a bit too crunchy to allow a gutta percha point to slide to full length through it. As was noted in section 3, condensing gutta percha into the material reduces the amount of CaO material left in a root, and compromises its ability to alkalinize the dentin. That's contrary to the theory we're working with here. A paste filling of CaO without gutta percha works best.

7. Check that the CaO filling has hardened.

Here is where the use of CaO becomes a lot less efficient than gutta percha. We truly hope that we can one day prove the stuff is worth the trouble of the extra appointments it requires by leaving treated teeth healthier. We shall see.

Here is a typical routine: When the canal is filled, schedule a 15 or 20 minute appointment for a buildup, prefab post-and-core, or access filling, a week or two later. Re-open the access and probe the canal with a file. If the CaO filling has not set, you will be able to slip right down the canal as you would into a Ca(OH)₂ dressing. In that case, rinse it out, reapply new material, and re-appoint the patient for another week or two. If, instead, your file meets resistance, it's set, and you're ready to proceed with the restorative. Sometimes the set is stony hard, while at other times it seems more compacted yet able to be picked out. Most practitioners would leave it at that stage.

Pretty inconvenient, but it is essential to be certain that the CaO root filling has set. “Treatment failures” have generally proven to have soft material in the canals, meaning either that the once-set material has been re-dissolved by acids produced by a recurring infection, or it was never properly set in the first place.

The majority of cases do set hard on the first application, although there are lots of variants. It is not untypical to see two canals in a molar hardened nicely while the third is soft. You may use CaO as a treatment dressing, intending to rinse it out and reapply it one or two days later, only to find that it’s already set rock hard. It’s all just part of the dynamic nature of CaO root fillings. Think of a CaO filling that hasn’t set as the equivalent of a necessary Ca(OH)₂ treatment, and you won’t feel too frustrated by the phenomenon. It is rare, though, to have a canal filling still fail to harden after three applications. If your treatments begin to experience more frequent failures to harden, get a fresh kit of material, as your old stock may have absorbed too much moisture from the air.

8. **Post preparation.**

A fully hardened CaO root filling cannot be drilled for the post prep. If you intend to restore the tooth with a post, you must prepare the post space by removing some fresh CaO paste just after you place it. A convenient method is to dip out the paste to the appropriate length with a paper point

9. **Overfills.**

Some practitioners have reported that overfills cause post-operative pain, though most others have not seen it. Biologically, there is no problem with overfills of this highly biocompatible material, as it resorbs with no consequences. The extra alkalinity may promote better bone healing as well.



Figure 5 – An overfill resolves with with apical bone regeneration.

10. Radio-opacity.

The original Biocalex formulation contained 2/3 calcium oxide and 1/3 zinc oxide. The insoluble ZnO was used as an inactive ingredient, an extender to reduce the degree to which the material would expand into the water layer. Unfortunately, neither of these ingredients is radio-opaque relative to tooth structure, so a completed treatment was

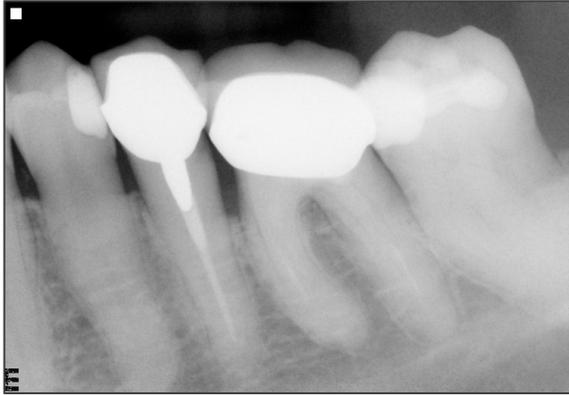


Figure 6 - Tooth #19 (36) successfully filled with Biocalex, but it is invisible on x-ray.

nearly invisible on a radiograph – a problem that has made a lot of dentists uncomfortable!

The original instructions for Biocalex stated that when a root could be instrumented to its full length, an additional 1/3 volume of zinc oxide should be mixed in. Yttrium oxide, Y_2O_3 , has physical properties identical to ZnO ¹⁴, and a completely benign toxicological profile.¹⁵ It is moderately radio-opaque, enough to make all the difference in the radiograph. By substituting yttrium oxide for the original zinc oxide, the radiolucency problem has been solved. All the clinical examples shown in this article were filled with a CaO/Y_2O_3 formula.



Figure 7 - Tooth # 30 (46) filled with conventional gutta percha, #31 (47) filled with CaO/Y_2O_3 formula for adequate radio-opacity.

We could use barium sulfate to give somewhat more dense radio-opacity, but many high-touch biocompatible practitioners try to stay away from barium. All barium compounds are considered toxic, with the exception of barium sulfate, and that only because of its exceptional insolubility.¹⁶



Figure 8 - The bismuth tooth presents certain problems despite excellent radio-opacity.

Bismuth oxide mixed with CaO makes a very radio-opaque fill, but it turns the tooth totally black!

10. **Retreatment.**

Most cases that are indicated for retreatment will be found to have soft material in the canals, and are easy to retreat. Occasionally there will be a tooth you'll want to retreat in which the fill in the canals is still rock hard. These cases should be considered for apical surgery, or carefully evaluated for fractured roots. But if you definitely want to re-negotiate the canals, soak the access cavity with 17% EDTA solution for a few minutes, and the material will soften up, allowing you to pick through it.

FDA Approvals for CaO root treatments:

510(k) Number, K941532: Biocalex

510(k) Number, K010176: yttrium oxide, under the trade name "Calex Conditioner"

510(k) Number, K013993: the mixture of CAO and Y2O3, under the trade name "Neocalex"

Research opportunities.

Every statement in this article that is not referenced to the scientific literature is backed only by accumulated clinical experience. Every aspect of CaO root canal technique still needs to be tested by experiment, and precious little has been. If the material is hard at the canal orifice, is it necessarily hard all the way to the apex? Do the chemical reactions described above really occur in the root canal? What is the canal filling like a year later, five years later? And most importantly, how disinfected do these teeth remain over time? Are we really reducing the long term accumulation of anaerobic toxins in the dentin tubules?

These questions should be investigated by academic researchers with access to animal subjects, but so far, this subject has not attracted the attention of those folks. The Guigand papers are about the only real science that has been published on the CaO root canal filling. It's a shame – there are clearly opportunities being missed for numerous PhD theses, while we continue to produce clinically acceptable root canal treatments in the field, justifying our work by trading anecdotes.

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A video presentation of this material, from the IAOMT meeting in Kansas city, March, 2005, is available [here](#).

- ¹ Vahdaty A, Pitt Ford TR, Wilson RF. Efficacy of chlorhexidine in disinfecting dentinal tubules in vitro. *Endod Dent Traumatol.* 1993 Dec;9(6):243-8.
- ² Araki, K, et al. Systemic distribution of formocresol containing ¹⁴C formaldehyde after pulpectomy.. *JDR* 1988; 67(SI): 274, A1291
- ³ Siqueira JF Jr, Lopes HP. Mechanisms of antimicrobial activity of calcium hydroxide: a critical review. *Int Endod J.* 1999 Sep;32(5):361-9.
- ⁴ Lynch, E, ed. Ozone: the revolution in dentistry. Quintessence Publishing, Surrey, UK. 2004
- ⁵ Schoop, U, et al. The use of the erbium, chromium:yttrium-scandium-gallium-garnet laser in endodontic treatment: The results of an in vitro study. *JADA* July 2007
- ⁶ Gordon, W, et al. The antimicrobial efficacy of the erbium, chromium:yttrium-scandium-gallium-garnet laser with radial emitting tips on root canal dentin walls infected with *Enterococcus faecalis*. *JADA* July 2007
- ⁷ Bernard, PD, Therapie Ocalexique, Editions Maloine, Paris, 1967.
- ⁸ Minana M, Carnes DL, Walker WL. pH changes at the surface of root dentin after intracanal dressing with calcium oxide and calcium hydroxide. *J Endodon* 2001; 27:43-45.
- ⁹ Guigand M, Vulcain JM, Dautel-Morazin A, Bonnaure-Mallet M. An ultrastructural study of root canal walls in contact with endodontic biomaterials. *J Endodon* 1997; 23:327-330.
- ¹⁰ Guigand M, Vulcain JM, Dautel-Morazin A, Bonnaure-Mallet M. In vitro study of intradental calcium diffusion induced by two endodontic biomaterials. *J Endodon* 1997; 23:387-390.
- ¹¹ Esberard RM, Carnes DL, del Rio CE. Changes in pH at the dentin surface in roots obturated with calcium hydroxide pastes. *J Endodon* 1996; 22:402-405.
- ¹² Esberard RM, Carnes DL, del Rio CE. PH changes at the surface of root dentin when using root canal sealers containing calcium hydroxide. *J Endodon* 1996; 22:399-401
- ¹³ Minana, op. cit.
- ¹⁴ Handbook of Chemistry and Physics, 73rd Edition. David R. Lide, editor. CRC Press, Boca Raton, Florida. 1992
- ¹⁵ Rare Earth Poisindex, Meditext Medical Management, in TOMES System, KM Hurlburt, editor. Micromedex, Inc, Englewood , Colorado. Edition expires February 2001.

¹⁶ Barium Salts Poisindex, Meditext Medical Management, in TOMES System, KM Hurlburt, editor. MICROMEDEX(R) Healthcare Series Vol. 107 expires 2/2001