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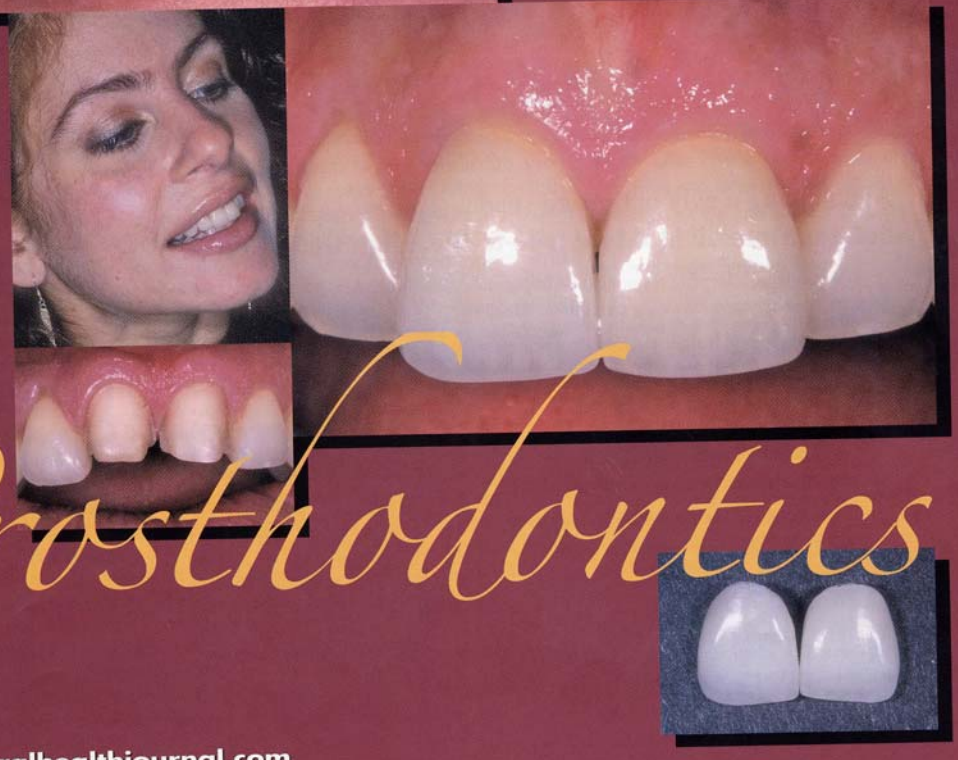

Prosthodontics

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The New Frontier: Minimally Invasive Dentistry and Ozone Aerotherapy

Stephen Gaines, BSc, DDS & Kenneth S. Serota, DDS, MMSc

In the early 1900's, dental caries was considered "gangrene" of the teeth, which mandated nothing less than extraction. This radical treatment approach was replaced by the extension for prevention restorative concept introduced by Dr. Black and sophisticated by others throughout the twentieth century as the microbiological model of dental disease took hold. Known as macro-dentistry, it promoted the complete removal of all carious tooth structure without regard for structural or biologic implications.

The advent of fluoride-reinforced enamel took caries "underground" as it became a sub-surface disease initiated through niche areas of fissure systems, structural defects, and areas of poor accessibility for maintenance. In spite of the focus on prevention in the waning decades of the last century, the profession has been resistant to move away from the macro-treatment model.

This article seeks to acquaint the reader with the evolving paradigm of Minimally Invasive Dentistry (MID) and the clinical application of ozone (O3) aerotherapy to complement the efficacy of this new treatment perspective (Fig. 1). The tools, technologies and techniques of MID reflect a radical change from the macro-trends embraced by dentistry throughout the twentieth century. An equally radical modification of the current mainstream clinical continuum is required in all facets from assessment and diagnosis to the rendering of treatment.

> "The professional man has no right to be other than a continuous student."
> *GV Black*

FIGURE 1—Paradigm Shift: "The basic principle of minimally invasive dentistry is to preserve as much of the natural tooth structure as possible while at the same time encouraging remineralization of early lesions to inhibit further progression." (Featherstone, 2004)

There are realities in the macro-dental model of treatment that cannot be ignored; recurrent caries, restoration failure, and irreversible pulpal damage will invariably persist in spite of our best efforts to eradicate them. "The clinical practice of minimally invasive dentistry is the application of a "systematic respect for the original tissue." This implies that the dental profession recognizes that an artifact is of less biological value than the original healthy tissue."[1]

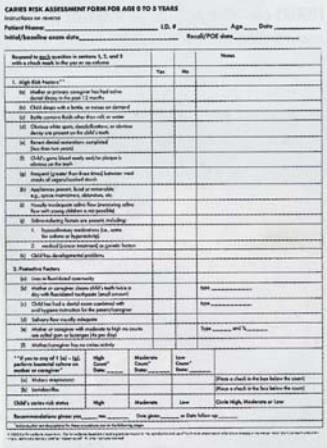

FIGURE 2—The CAMBRA worksheet helps to integrate caries control into comprehensive treatment planning.

In the macro-dental model, cavitations were significant and obvious, thus assessment and diagnosis centered on decisions related to the number of pins needed for filling retention, the requirement of a full coverage restoration, or the necessity of endodontic therapy. In the paradigm of micro-dentistry, assessment and early diagnosis are pivotal in achieving the goals of respect for original tissue and preservation of tooth structure as detection is that much more subtle. The protocol defined by the Caries Management by Risk

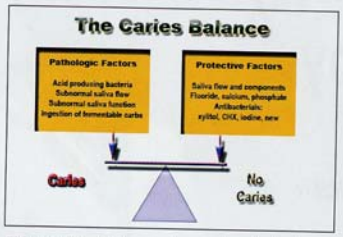

FIGURE 3—Schematic adapted from Featherstone JD, Am J Dent. 1999.

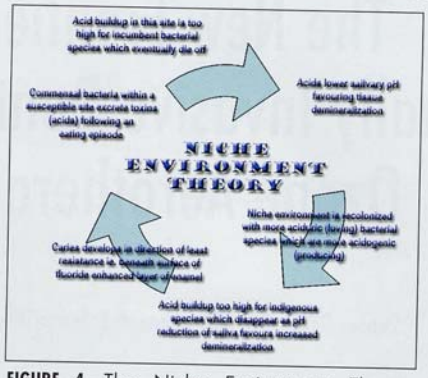

FIGURE 4—The Niche Environment Theory. Fermentable dietary carbohydrates + saliva + susceptible site + specific bacteria + time = cariogenesis.

FIGURE 5—HealOzone (Curozone, USA and KaVo): The ozone (O3) generator and application device (silicone suction cups seen above).

FIGURE 6A—Pre-operative view of pit and fissure decay in tooth #3.7.

FIGURE 6B—Silicone suction cup enveloping the tooth during ozone delivery.

FIGURE 6C—Application of reductant/remineralization fluid containing calcium, phosphate, fluoride and xylitol to initiate the remineralization process.

FIGURE 7A—Pre-operative view of open cavitated lesion in tooth #1.7.

FIGURE 7B—Soft unstructured caries and poorly supported enamel removed.

FIGURE 7C—Glass ionomer interim restoration.

FIGURE 7D—HealOzone remineralization patient kit containing high level fluoride paste and rinse with calcium, phosphate and xylitol.

FIGURE 7E—Image taken immediately after removal of the glass ionomer shows hardened, remineralized dentin 5 weeks post-operative.

FIGURE 7F—Final restoration has preserved the disto-buccal and occlusal segment of the tooth.

FIGURE 8A—Pre-operative view of large Class V caries in tooth #2.3. Note the partially remineralized surface layer.

FIGURE 8B—Laser removal of superficial structure reveals underlying carious dentin.

FIGURE 8C—HealOzone applied to the cervical lesion.

FIGURE 8D—Inner layer of glass ionomer restorative replaces lost dentin and provides direct fluoride to the micro-environment.

FIGURE 8E—Final restoration after addition of the outer layer of composite resin.

Assessment (CAMBRA) (Fig. 2) identifies the presence of certain factors, including behavioral patterns, which could contribute to an individual's caries risk.[2]

New tools and technologies in the micro-dental armamentarium which include laser fluorescence spectroscopy (DIAGNOdent®, KaVo America Corp, Sumas WA), magnification of various types, transillumination, and dental x-rays (conventional and digital) can all contribute to the early detection and diagnosis of "hidden caries" (caries in the absence of surface cavitation). As the goal is to detect, diagnose and treat caries prior to the occurrence of irreversible loss of tooth structure, a basic theoretical working knowledge of the caries process is essential. Two important concepts in this regard are: The Caries Balance (Fig. 3) and the Niche Environment Theory.

The Niche Environment Theory has become the accepted model by which the development of caries is understood to occur. Specific cariogenic bacteria establish a "niche environment" in the fissure sys-

As dental demographics changed and prevention based dentistry became the standard of care, the new challenges of managing and treating an aging population who have retained rather than lost their teeth needed to be addressed. This was of particular concern in regard to root surface caries and the increased susceptibility of exposed root surfaces in elderly patients.

Professor Edward Lynch and others have shown that ozone, delivered through a specially designed generating device (Fig. 5) at a concentration of 2100 ppm and at a rate of 615 cc per min for a time >10 sec, can substantially reduce and neutralize cariogenic, pathogenic micro-organisms and contribute to the reversal of both root caries and pit and fissure caries.[13-18]

Ozone's effectiveness as a bactericidal agent, viral and fungal deactivator as well as its ability to kill bacteria 3000 times faster than chlorine-based agents has made it the primary disinfection source for many water utilities globally. Ozone maximizes "biological combustion" of both energy supplies (carbohydrates) and toxins, through highly effective oxidation of compounds, leading to the elimination of toxic substances.[19,20] It has been clinically demonstrated to eradicate micro-organisms associated with caries development, promote natural remineralization of enamel following treatment, remove volatile sulphur compounds associated with halitosis, and whiten discoloured caries by destroying the chromatic chemical rings.

CLINICAL APPLICATIONS, TECHNIQUES AND CASES

As demonstrated by the following clinical cases, ozone aerotherapy with HealOzone has a variety of clinically relevant applications. The range covers all aspects of restorative dentistry from micro-dentistry to minimally invasive approaches within macro-dental situations (including endodontics). As there are always consequences to aggressive tooth structure removal, regardless of the time taken to become apparent, the concept of ozone assisted remineralization is of significant importance to the future of dentistry.

In many of these cases, the use of "conventional" dental methods would have resulted in the incomplete elimination of bacterial pathogens and their acids, further compromise of otherwise retainable tooth structure, and encroachment upon or direct infiltration into the pulpal space. With the proper application of ozone technology, eradication of the infectious microorganisms, neutralization of the acids formed, remineralization and hardening (not removal) of the previously infected dentin, and restoration with minimally invasive techniques was possible. The preservation and maximal retention of natural tooth structure was optimized.

CASE ONE

The ultraconservative treatment of occlusal fissure caries (Fig. 6a) with HealOzone prior to sealing the fissures is demonstrated. Ozone was infused under vacuum seal for 40 seconds (Fig. 6b) and the reductant/remineralization fluid (pH balancer) was dispensed onto the tooth and agitated with a microbrush for 20 seconds (Fig. 6c). With the fissures free of cariogenic bacteria and their acid byproducts, the tooth can now be conservatively restored. Classic pit and fissure sealants have shown unsatisfactory longitudinal results largely due to residual micro-organisms.[21,22] Elimination of the micro-caries prior to sealing has, for some time now, been suggested. Macro-dentistry often employs more aggressive conventional drilling and filling concepts to achieve this removal. Others have used less invasive techniques such as air abrasion or lasers. Ozon therapy here would be considere a non-invasive technique.

CASE TWO

Patient presented with a dee gross cavitation undermining non-supporting cusp (Fig. 7a) Here, an aggressive macro-denta resolution may have involved con tinuous excavation of carious dentin in close proximity to the pulp, and opening of the lesion well into the occlusal table and through the entire distobuccal Instead, a minimally invasive approach was utilized. Without anesthesia, the soft unstructured caries was first removed with an excavator leaving the structured leathery "infected" dentin intact (Fig. 7b). Undermined weak cavo-surface enamel was smoothed gently with a slow speed round bur and excavator. The lesion was ozonated with for 60 seconds and the reductant/remineralization fluid was scrubbed into the lesion for 20 to 30 seconds. A small cotton pledget moistened with the reductant fluid was placed in the lesion against the dentin. Glass ionomer (GI) (Fuji IX GP™, GC America Inc. Alsip, IL) was placed in the cavitation as an interim material (Fig. 7c). After 5 weeks of home use of the HealOzone remineralization patient kit (Curozone USA Inc®. Aurora, ON) (Fig. 7d), the patient returned. Again without anesthesia the glass ionomer was removed by "punching" through it with a small round bur and then "chipping" it out with an excavator. The results of the treatment were examined directly (Fig. 7e). The remineralized dentin was tactilely hard by explorer examination. The cavitation was then restored using a "sandwich" technique with a GI (Fuji IX GP™, GC America Inc. Alsip, IL) dentin replacement layer and direct bonded composite surface layer maintaining the strength and integrity of the tooth's original form and structure (Fig. 7f).

FIGURE 9A—Leaking amalgam restoration with recurrent decay in tooth #7.4.

FIGURE 9B—Light-cured flowable block-out resin (Ultradent® LC Block-Out Resin, UPI, South Jordan, UT) filling the interproximal embrasures.

FIGURE 9C—Final GI/composite restoration in tooth #7.4.

FIGURE 10A—Sub-gingival mesiobuccal recurrent decay on molar bridge abutment.

FIGURE 10B—Tissue position after laser gingival re-contouring and conservative caries removal.

FIGURE 10C—Ozone applied to the cervical lesion.

FIGURE 10D—Core patched with GI restorative; final preparation completed.

tem. As this environment cannot be effectively altered by conventional preventative measures, these acidogenic and aciduric bacteria remain for potentially long periods of time. This continuous acid exposure leads ultimately to the demineralization of the dental hard tissues. The subsequent lower pH (high acidity) in the overall oral environment keeps the balance in favour of demineralization (Fig. 4).

The prevention of demineralization and the promotion of remineralization are the ideal achievements of ultraconservative minimally invasive dentistry. Featherstone and Ten Cate have shown that "remineralized enamel or dentin is more resistant to subsequent acid challenges...".[3-5] Controlling the balance within the niche environment in order to prevent demineralization and promote remineralization is where the innovation of ozone therapy and associated technologies is proving invaluable. "... the bacterial infection must receive antibacterial therapy at the same time remineralization is being enhanced."[6]

OZONE (O3) IN THE HEALTH SCIENCES

In 1857, Werner von Siemens, developed the first ozone generator and in 1870 the first reported therapeutic use of ozone was reported for blood purification by Lender. Ozone was initially considered as a disinfectant for drinking water by Ohmuller in 1892 due to its action on bacteria and other micro-organisms.[7] In 1885, Kenworthy published a paper discussing ozone's early potential medical applications.[8]

Its uses in medicine expanded during the latter half of the twentieth century. They ranged from autohaemotherapy in the treatment of different vascular disorders and viral diseases, to the treatment of senile dementia.[9,10] As an extrapolation of its medical use, the use of ozone in dentistry began as a healing and antibacterial agent during dental surgeries in the form of ozonated water.[11,12]

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FIGURE 11A—Large area of caries in tooth #6.1 prior to treatment.

FIGURE 11B—4 weeks after ozonation/ remineralization protocol.

FIGURE 11C—Final bonded composite restoration tooth #6.1.

CASE THREE

The patient's chief complaint on presentation was dissatisfaction on smiling and a desire to correct the appearance prior to an important social function in a few days. No symptoms were present and a long history of chronic soft drink consumption was reported. Clinically, the surface of the class V lesion on tooth #2.3 was dark, discoloured, and irregular; however it was reasonably firm to the touch with an explorer (Fig. 8a). This was an example of the caries balance at work. The body's efforts to remineralize however, was limited when the underlying microbiologic problem (cariogenic bacteria) was not addressed. Traditional macro-dental treatment would call for the complete removal of infected dentin which would risk the health of the pulp and compromise the tooth's structural integrity. Endodontic therapy with the possibility of crown treatment could have become part of the possible outcomes.

Using a minimally invasive approach and without anesthesia, the surface structure was removed and the weak cavosurface enamel beveled using an Er:YAG laser (KEY Laser 3, KaVo America Corp. Lake Zurich, IL). This revealed the underlying carious dentin (Fig. 8b). The unstructured soft caries was removed conservatively with an excavator and the lesion was treated with ozone for 120 seconds (Fig. 8c). The reductant/remineralization fluid was scrubbed into the lesion for 20 to 30 seconds. In this case, as the esthetic urgency of the patient was his priority, a final restoration was placed which again utilized a "sandwich" technique of a glass ionomer inner layer (Fig. 8d) and a direct bonded composite (Esthet-X®, Dentsply International, York PA) outer layer (Fig. 8e). The patient was then counseled regarding the necessity of a low acid diet and a home care regimen which included use of the remineralization patient kit.

This minimally invasive technique allowed the retained, sterilized, natural and otherwise healthy tooth structure to remain as the thick protective layer between the cavitation floor and the pulpal tissue.

CASE FOUR

This young patient presented with recurrent decay in tooth #7.4 (Fig. 9a). Here, local anesthesia and conventional techniques were used to remove the failed amalgam filling. Ozone therapy was chosen as a conservative alternative to invasive caries removal which conceivably would have led to irreversible pulpal damage.

After conservative excavation of the soft recurrent caries, flowable blockout resin was used to fill the interproximal embrasure spaces in order to help establish the vacuum seal needed for the HealOzone silicone cup (Fig. 9b). The tooth was ozonated for 60 seconds and the reductant/remineralization fluid scrubbed in the preparation for 20-30 seconds. The GI/ bonded composite sandwich technique was used to protect and restore the tooth (Fig. 9c). The combination of ozone sterilization and restoration with a protective, acid resistant and bonded restoration, greatly minimizes any further risk of recurrent decay.

CASE FIVE

In this case, recurrent decay was clinically detected beneath the margin of a bridge. Removal of the bridge revealed that the decay at the mesiobuccal margin extended subgingivally (Fig. 10a). The subgingival decay was accessed by recontouring the tissue using an Er:YAG laser. The laser and a caries removal bur and excavator were then used conservatively for caries management (Fig. 10b). The buccal, occlusal, and lingual surfaces were each ozonated for 60 seconds (Fig. 10c) and the reductant/remineralization fluid was scrubbed into these areas. The core of the prepared tooth was rehabilitated buccally and occlusally using glass ionomer (Fuji IX GP™, GC America Inc. Alsip, IL) and the final preparation and impression completed (Fig. 10d).

FIGURE 12A—Pre-operative clinical presentation of tooth #1.7. Note the seemingly innocuous occlusal fissure.

FIGURE 12B—Initial access with Er:YAG laser.

FIGURE 12C—Completed cavity preparation. Note the irregular dentin surface due to intact infected dentin.

FIGURE 12D—The embrasure has been blocked-out with light-cured flowable resin to facilitate vacuum seal for HealOzone aerotherapy.

FIGURE 12E—Fuji Triage® glass ionomer (GC America Inc. Alsip, IL) interim restoration.

FIGURE 12F—Removal of the glass ionomer 4 weeks post-operatively. Note the smooth remineralized dentin surface.

FIGURE 12G—Final GI/composite restoration placed in tooth #1.7.

This minimally invasive approach to a macro-dental situation using ozone and remineralization eliminated the recurrent caries a minimized further recurrent caries risk thereby increasing the longevity and integrity of restoration and tooth.

CASE SIX

A three-year-old patient presented for the first time to a dental office with a large carious class IV fracture of the primary maxillary left central incisor [#6.1] (Fig. 11a). The parent indicated that no symptoms had been present and with their permission, the soft unstructured carious dentin was removed, without anesthesia, using a spoon excavator. The tooth was ozonated for 60 seconds and the reductant/remineralization fluid was scrubbed in for 20 seconds. The lesion was left open and specific instructions were given to the patient's mother to brush the paste from the HealOzone remineralization patient kit directly into the lesion. The patient returned four weeks later with healthy, sound intact dentin (Fig. 11b) and a final bonded composite restoration was placed (Fig. 11c). The pulpal tissue was preserved and to date has remained asymptomatic.

CASE SEVEN

This case demonstrates the treatment of sub-surface class II caries. Upon routine radiographic exam mesial-interproximal caries was found in the upper right second molar (#1.7). The clinical presentation was remarkable only for a "stained" fissure (Fig. 12a). Without anesthesia an Er:YAG laser was used to access the lesion through the enamel (Fig. 12b). When the enamel preparation was complete, the soft unstructured carious dentin was excavated leaving the "leathery" infected dentin

FIGURE 13A—Teeth #'s 4.6 and 4.7 demonstrate inadequate root canal procedures. The open canal in the coronal one-third of the root of tooth #4.5 and the calcification of the residual component of the canal space are suggestive of either a split in the root canal system or a calcific pathosis.

FIGURE 13D—The post operative radiograph shows the root canal procedures completed, the coronal seals in place over the orifices and chamber floors in the molars and calcium hydroxide sealed in the chamber of the bicuspid.

FIGURE 13B—The handpiece, silicone cup and canula used to introduce the ozone into the root canal systems.

FIGURE 13C—The silicone cup is fit over the coronal tooth structure to create a vacuum seal and the ozone gas is then bubbled through the NaOCl in each of the root canal spaces.

intact (Fig. 12c). The interproximal embrasures were blocked out using a flowable resin material (Fig. 12d) and the lesion was ozonated for 60 seconds.

The reductant/remineralization fluid was then scrubbed into the lesion for 20 seconds. A small cotton pellet moistened with reductant fluid was placed against the ozone treated dentin (away from the cavosurface margin) and a glass ionomer interim material was placed (Fuji Triage®, GC America Inc. Alsip, IL) (Fig. 12e). The patient was instructed to maintain a low acid diet and on the use of the HealOzone remineralization patient kit. The patient returned after four weeks reporting no problems. Without anesthesia the glass ionomer was removed and the remineralized dentin was visually and tactiley confirmed (Fig. 12f). A final restoration was then placed using the GI / bonded composite "sandwich" technique (Fig. 12g). This remineralized tooth structure now provides an acid resistant barrier to further cariogenic bacterial assault.

MID and Endodontics

Endodontics is the prevention and treatment of apical periodontitis. In spite of the continuing sophistication of equipment and techniques within the endodontic armamentarium, root canal success is inextricably linked to the absolute eradication of microflora [23,24] and that totality is not yet achievable.[25] Contentious issues abound; should one-visit or multiple visit therapy be used for retreatments, necrotic cases and those with apical lesions present,[26] is the use of calcium hydroxide therapy as an interim treatment medicament valid and purposeful,[27] what constitutes the ideal irrigation protocol in terms of solution, volume, and time within the root canal space? If polyester obturating materials and resin sealers create an impervious monobloc and therefore entomb the residual microflora, will success rates increase,[28] is coronal sealing an integral component of the root filling?[29] In all instances, the underlying theme is the need for optimal elimination of microflora.

The introduction of ozone has enabled the clinician to ozonate sodium hypochlorite (NaOCl), the most ubiquitous of the endodontic irrigants. Ozonated NaOCl releases hypochlorous acid which reacts with insoluble proteins to form soluble polypeptides, amino acids and assorted by-products. It acts as an organic and fat solvent, degrading fatty acids and transforming them into fatty acid salts and glycerol thus reducing the surface tension of the residual solution. The chloramines produced interfere in cell metabolism and cause destruction of cell walls and cytoplasmic membranes of microorganisms.[30] Ozonation of NaOCl in a negative pressure differential environment as created by HealOzone should enable one visit root canal therapy in cases where the literature suggests the need for multiple visit treatment.[31]

CASE EIGHT

The patient presented with a history of root canal therapy and full

coverage restorations on teeth #'s 4.6 and 4.7 done approximately three months prior (Fig. 13a). She had persistent masticatory sensitivity in the region and continued response to thermal challenge, particularly hot liquids. Diagnostic testing determined that tooth #4.5 was necrotic and in addition to the percussion and palpation sensitivity evidenced by both molars, the radiographs suggested that the obturation of the root canal system was suspect. The patient accepted the need for retreatment of the molars and treatment of the bicuspid.

Access through the crowns revealed leakage within the core structure and the crowns were removed. Traditionally, the root fillings would be removed, the canals debrided, shaped and disinfected and an interim treatment dressing of calcium hydroxide placed in all canals for a period of one to four weeks after which time the root canal systems would be obturated and coronally sealed. In this instance, the NaOCl was ozonated for 20 seconds a number of times throughout the procedure and for 60 seconds at the completion of the shaping phase (Figs. 13b & c). The canals were then soaked for 5 minutes with BioPure™ MTAD™ (Dentsply/Tulsa Dental, Tulsa OK), the material flushed out and the canals sealed with HiFlow Resilon™ and Epiphany™ sealer (Pentron Corp., Wallingford, CT) (Fig. 13d). The case will be monitored for healing for a period of 18 to 24 months.

Mainstream dentistry and the educators teaching future generations need not embrace minimally invasive dentistry, but acknowledgement and investigation of the associated diagnostic and treatment technologies is sensible. All new technologies are met with disavowal until treatment outcomes and evidence based science can validate their worth. It seems prudent to suggest that if it eradicates microorganisms from the niches in which they have managed to survive, in concert with minimally invasive dental approaches, ozone can and should turn dentistry away from the 'Dark Ages' of tissue amputation and present the profession with a gold standard for prevention and disease arrest and reversal. **OH**

Dr. Gaines maintains a private practice in Oakville, ON. His practice encompasses all aspects of general dentistry with emphasis on minimally invasive techniques and technologies. Dr. Gaines is a Fellow, Founding and Lifetime member of the World Congress of Minimally Invasive Dentistry (WCMID).

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Dr. Serota is a program coordinator for the Continuing Education Department at the University of Toronto and maintains a private practice specializing in endodontics in Mississauga, ON.

Oral Health welcomes this original article.

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