Novel Irrigants for Canal Disinfection

Author_ Liviu Steier, Germany and the United Kingdom

(Editor's note: The following is a summary of Dr. Steier's presentation at the Roots Summit VI, held June 22–24 in Amsterdam by the Roots cybercommunity. Our thanks to Robert M. Kaufmann, DMD, MS [Endo] for providing the transcription.)

_The goals of irrigation, both in the coronal and apical third of the canal system are:

- Debris and smear layer removal
- Disruption of adhesive biofilm
- Disinfection
- Opening of the dentinal tubuli

Our disinfection/irrigation protocol should be tailored to address different clinical situations. We can divide irrigation protocol into two groups: acute apical periodontitis (AP) and chronic AP.

_Irrigants of interest

Common irrigants include NaOCl, EDTA, citric acid, chlorhexidine (CHX), and Factor "X" (electrochemical activation [ECA] of different solutions). We must recognize the potential toxicity of NaOCl and the effects of ClO3- and ClO2- (the chlorates). In mammals, these chemicals arise from oxidative damage to red blood cells, hemolytic anemia, and methaehemoglobin formation. It is also cytotoxic for fibroblasts. Therefore, we are searching for possible alternatives.

The new approach involves two areas of investigation: ozonization and electrochemical activation. Irrigants of interest include:

- Ozonized water
- Ozonized NaOCl
- ECA water
- ECA NaCl (saline)
- Ozonized ECA water
- Ozonized ECA NaCl (saline)

After 18 months of study (the results are still being evaluated), we have narrowed the irrigation groups down to these five areas of interest:

- Water
- NaOCl
- NaCl (saline)
- Ozone
- Electrochemical activation

Ozone generators are being produced but are not FDA approved. This is still years away. There is a big difference between the two ozone-generating units now being produced. In the design currently available (Neo Ozone Water-S, KORM Electronics, Atsugi, Japan), ozone is liberated into the workspace and we know that ozone is toxic. The newer designed unit (HealOzone, KaVo Dental, Biberach, Germany/Lake Zurich, Ill.) generates as much as six times the ozone as the other unit. Safety is assured by designing the unit to be functional only when a vacuum is achieved over the endodontic access by means of an airtight "cap." This seals the access when the ozone-generating device is applied. Without the tight seal and without a vacuum, the machine will not deliver the ozone. Caps (8, 6, 5 and 4 mm sizes) are made of silicon, and can therefore be customized by adding a silicon-based material to them to make the airtight connection to the tooth.

Electrochemical activation (ECA) is a product of the 1970s and was patented in the former Soviet Union by Dr. V.M. Bakhir. Since his papers and ECA patents were published in Russian, they have been difficult to publicly review. This technology was first used for drilling. ECA fluids also have applications in endodontic preparation. All ECA devices are more or less electrolysis of water or saline.

The quality of water that comes into our offices can

Fig. 1

Fig. 1_HealOzone unit.

vary from street to street, even in the same city. In older dental units, biofilm problems (as a result of long-term exposure to these sources) can be a big problem. Higher quality (cleaner) water can be obtained by deionization or distillation.

Water quality is also affected by temperature of action and pH. Reverse osmosis technology is used in homes to improve water quality to that of the level of bottled water.

_Ozone in endodontics

The HealOzone unit looks like a standard hand piece with a protruding needle and a plastic cap that fits over the access (Fig. 1). The needle goes in the canal and delivers the ozone. Our initial studies with this device were disappointing and did not correspond to the manufacturer's claims. Since ozone is applied as a gas, it can also be transported by a "carrier" media, which may allow it to enter the deeper portions of the canal system and hard tissue. We studied ozonized water, ozonized ECA water, and ozonized ECA NaCl (saline) as well as ozonized NaOCl.

Many studies have been published on the ozonization of solutions, with varying results. The first studies used water. Nagayoshi et al. ("Antimicrobial Effect of Ozonated Water on Bacteria Invading Dentinal Tubules") showed that ozonated water had nearly the same antimicrobial activity as 2.5% NaOCl during irrigation, especially when combined with sonication, and showed a low level of toxicity against cultured cells.

The Nagayoshi study used a Neo Ozone Water-S unit that produced about one-tenth the ozone of the HealOzone (Kavo) unit we are currently testing. Therefore, we must carefully scrutinize the results of these studies (i.e., what solution did they use and what unit delivered the ozone?)

In Cho et al.'s study ("Disinfection of Water Containing Natural Organic Matter [NOM] by Ozone Initiated Radical Reactions"), NOM is the term used to describe the complex mixture of organic material such as humic acids, hydrophilic acids, and hydrocarbons that are present in all drinking water. The type of NOM and the pH have considerable effects on the percentage of disinfection by hydroxyl radical, which ranged from 20% to 50%.

This is important because dissolved impurities in modern water supplies (ions such as calcium, sodium, chlorides, etc.) can affect the properties of the ozone delivery. Ozonization of water by the cleavage of humic acid promotes bacterial recontamination. Therefore the type and source of water used in the studies can actually promote recontamination if the "correct" type of water is not used.

One way to "clean" the water is by deionization. Deionization is a process that removes ions from the water via ion exchange. Positively charged ions (cations) and negatively charged ions (anions) are exchanged for hydrogen (H+) and hydroxyl (OH-) ions, respectively, due to greater affinity for other ions.

Water quality is measured by its electrical conductivity and electrical resistance. (It is the amount of ionized substances, or salts, dissolved in the water that de-

Fig. 2_Sterilox generator.

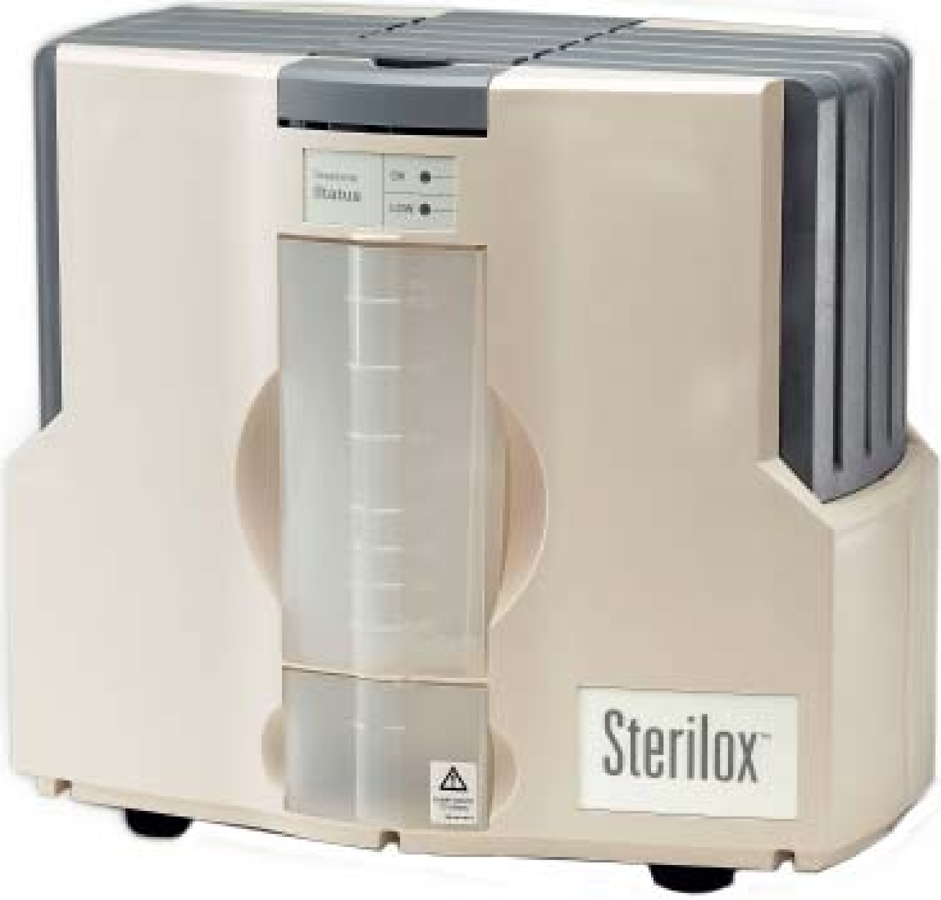

Fig. 2

termines the water's ability to conduct electricity. Poorer-quality water has a lower resistance and conducts electricity better, while better-quality water has less ionized substances and conducts water less easily.) Most dental units have very poor-tasting water and the purity is generally not very high. Dental unit purity generally falls slightly above or below the "city supply" purity level, which is far from that of deionized or distilled water (depending on location and age of unit).

Reverse osmosis units (for home use) use pressure and a membrane filter to remove impurities (ions) from water. We also must understand that distilled water reacts with atmospheric CO_2, which brings the pH of distilled water in an open-air container down to about 5.8.

A quick, unscientific test using a total dissolved solids (TDS) readout shows the total amount of mobile charged ions, minerals, salts, or metals dissolved in a given volume of water, which is measured in parts per million (ppm). Distilled water had a value of 0 to 1. My dental unit value was 239 and the main water line was 191.

In the absence of dissolved electrolytes, water will not conduct electricity, so no electrolysis occurs. This means that if we want to use this pure water we will have problems. This is why manufacturers introduced saline for electrolysis and to obtain the two (cation and anion) solutions.

Nagayoshi et al. ("Efficacy of Ozone on Survival and Permeability of Oral Microorganisms") found that ozonated water should be useful in reducing the infections caused by oral microorganisms in dental plaque. Again, they used a Neo Ozone Water-S unit that produced about one-tenth the ozone of a HealOzone unit.

Hems et al. ("An In Vitro Evaluation of the Ability of Ozone to Kill a Strain of *E. faecalis*") showed there were significant reductions of bacteria in the unwashed and washed broth cultures following 240 seconds of application. They concluded that ozone had an antibacterial effect in planktonic E. faecalis cells and those suspended in fluid, but little effect when embedded in biofilms. Its antibacterial efficacy was not comparable with that of NaOCl under the test conditions used. However, the tests used devices and technology that produced low levels of ozone.

_Electrochemical activation (ECA)

ECA is the process of passing a diluted saline solution through a flow-through electrolytic module (FEM) to generate (by electrochemical energy conversion) environmentally friendly, highly active solutions of anolyte and/or catolyte. Electrolysis of water is what is known as a "redox" reaction. That means that electrons are being moved from one molecule to another.

At the anode, electrons are removed from the water and it is oxidized, as in $2H_2O$-> O_2+4H+4e-

At the cathode, electrons are added to the water as it is reduced, $2H_2O$ +4e- $2H_2$ -> 4 OH-

So at the anode, we get oxygen gas and hydrogen ions; at the cathode we get hydrogen gas and hydroxide ions.

Studies performed with ECA must be closely scrutinized because the solutions used in the studies can be very different depending on input solutions and the effects of the device used for ECA. Different FEMS can deliver different solutions.

ECA involves chemical and electrical processes (without additives). Chlorine gas can be formed if the electrodes in the unit are made of carbon. If NaCl is added to the water, Cl ions in the water can oxidize to chlorine and combine with the OH ions to form hypochlorite (Cl_2 + 2OH- ‡ Cl- + OCl- + H_2O). The question is: What is the technology we are using? And what solutions are being created?

_Source solutions for ECA

NaCl water solutions with no more than 5.0 g/L concentration or fresh water of less than 1.0 g/L mineralization--what is best for ECA? To obtain the best end solutions with the ECA, NaCl water solutions with no more than 5.0 g/L concentration or fresh water of less than 1.0 g/L mineralization is needed.

_Electro treatment

This is accompanied by controlled mass transfer in the inter-electrode space with minimal heat generation and with obligatory creation of conditions for the closest contact of each microvolume of liquid under treatment with the dense and/or diffuse part of the double electric layer in the electrode surface where the electric field intensity reaches several million volts/cm.

_Catolyte

This is an anti-oxidizing, mild alkaline solution with a pH range of 10.5–12. The most common application for the catolyte is as a mild cleaning, detergent, and degreasing agent.

By adding a sodium chloride solution to an ECA machine we get a "metastable solution" which has:

_ Changed pH of solution and high oxidation reduction potential
_ Free radicals (high electron activity) in the catolyte
_ Extremely low electron activity in the anolyte

(When we are discussing potential bonding of resin-based endodontic filling materials, we need a reductant for the final irrigation. If we don't, the free oxygen radicals can inhibit polymerization of the material.)

This "metastable solution" has excessive physical and chemical excitation. This gradually dissipates with time, but how long are the solutions stable? They can be kept for seven days as long as they are in brown bottles and stored in the refrigerator.

_Anolyte

This is a strong oxidizing solution with a pH range of 3.5–8.5. The most common application of anolyte is as a biocidal agent.

FEM types include:

- *Emerald device:* mainly a technology to clean water of microorganisms, organic mixtures, and heavy metal ions. Used in the purification of drinking water.
- *Stel device:* used for synthesizing electrochemically activated washing, disinfectant, and sterilizing solutions. Mainly used in medical prevention and sanitary/epidemiological institutions. These devices deliver an anolyte of two types, acidic versions (pH <5) and neutral versions (pH 6–8.)
- The catolyte produced is also of two types, a neutral version (pH 0–7) and an alkaline version (pH >9).
- *Aquachlor device:* (the most endodontically important devices) are used in the electrochemical synthesis of gaseous oxidant mixture to form NaCl aqueous solutions. The main components of the oxidant gaseous mixture are molecular chlorine, chlorine dioxide, and oxygen, found at a ratio of 70:20:5:5%, respectively. The ratio depends on the particular device and can vary widely. This has great potential because we can increase the ozone production of the unit by ozonating the solution.

The most desired components from an anolyte are:
_ Free chlorine (ClO-)
_ H_2O_2 (hydrogen peroxide)
_ O_2
_ Ozone

Sterilox seems to be very promising based on it s titanium composition (Fig. 2).

Because ECA-activated solutions were first used in the drilling industry, I believe that (when ultrasonically

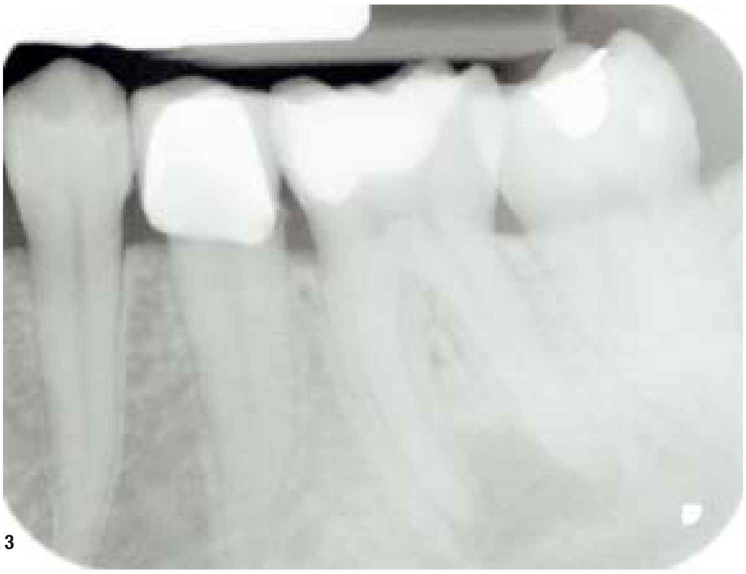

Fig. 3

Fig. 4

Fig. 5

activated) they may help us in our canal system preparation.

_Ozonization

It is important to remember that we wish to avoid the formation of chlorates. The mechanism of chlorate formation is:

O_3 (ozone) + OCl -> $2O_2$ +Cl-
O_3 (ozone) + OCl -> O_2 +ClO_2- ionic products of ozonization of NaOCl
O_3 (ozone) + OCl2 -> O_2 +ClO_3-

When NaOCl at pH 10–12 interacts with organic tissue it produces three reactions:

- Saponification, resulting in the creation of lipids
- Amino acid neutralization reaction
- Chloramination reaction

These three reactions are important in the disinfection of the root canal system. Studies have shown that the saponification reaction occurs only if we have enough free radicals. In our normal bleach solution, these free radicals are not found in high amounts, so the solution is called "lazy" because of its low saponification rate.

We want to use NaOCl solution at a pH of around 11 (where it is the most efficient) and where the maximum amount of hypochlorous acid is present. We should measure the pH of our NaOCl irrigation solutions to ensure maximum effect.

J.T. Marais ("Cleaning Efficacy of a New Root Canal Irrigation Solution: A Preliminary Evaluation" Int Endod J 2001;33:320-5) showed that the cleaning efficacy of electrochemically activated water in root canals was superior to NaOCl, producing cleaner surfaces and greater areas of smear layer removal. (But the technology used in the study was unknown.)

Several other studies have used various forms of ECA water. Gulabivala et al. ("Effectiveness of ECA Water as an Irrigant in an Infected Tooth Model," Int Endod J 2005;37:624-31) concluded that there was a difference and that ultrasonication was also a factor. This supported the reasons that the solutions were originally used for drilling.

Hata et al., ("Removal of Smear Layer in the Root Canal Using Oxidative Potential Water [OPW]," J Endod 1996;22:212-6) found that OPW used as an irrigant was as effective as 5% NaOCl or 17% EDTA for opening and keeping the dentinal tubules patent.

Hata et al., ("The Effectiveness of Oxidative Potential Water as a Root Canal Irrigant," Int Endod J 2002;34:308-17) concluded that OPW irrigation by syringe is effective as 5% NaOCl or 15% EDTA for removal of smear layer and debris. The description of the technology, again, was different than that of the inventor, Dr. V.M. Bakhir. SEM results showed the same results as in the Hata study.

Our studies conducted at Queens University Belfast Dental School incorporated the following solutions:

- *Ozonated water (ozone + water).* In the apical areas this solution really didn't do much. Smear layer and debris was present on the whole surface. In the area where the ozone-delivering needle was placed, there was some minor improvement in cleanliness. The more coronal areas were not cleaned at all.
- *0.5% NaOCl.* Not clean in the coronal area. No effect in the middle canal. Same for apical areas (not clean).
- *0.5% NaOCl and ultrasonics.* Some improvement and tubule patency was noted. The best cleaned areas again corresponded to the location and depth of the ozone-delivery tube.
- *Ozonated anolyte.* The coronal part showed improved cleanliness. The middle result showed less favorable results, but the apical portions showed bigger surfaces of cleaned dentin.

The studies will be repeated with higher concentrations of NaOCl to determine if the results improve.

Later studies with Rimaldi and Beer ("Antibacterial Power of Ozone-Activated NaOCl for Root Canal Disinfection," Universitat Witten/Herdecke) used the following solutions:

- 5.25% NaOCl
- 0.25% NaOCl
- 3 x 40 ozone activated 0.5% NaOCl
- 3 x ozone activated cleaned deionized water

These studies concluded that ozone-activated NaOCl 0.5% had a higher antibacterial effect than unactivated NaOCL 0.5%. The question is: What is the minimum concentration of NaOCl that we can use to get a good effect while at the same time limiting the toxic effects of the solutions of higher strength?

_Conclusions

Overall, we concluded that two different NaOCl solutions should be used for endodontic treatment: one for disinfection and one for smear layer removal. For disinfection we should use:

- NaOCl 5.5%
- Ethanol (to reduce surface tension)
- Elevate solutions to greater than 50 degrees C.

For smear layer removal, we should use:

- NaOCl 5.5% buffered to a pH of 11 (by using NaOH), and make sure the temperature is around 10 degrees C.
- Add H_2O_2 for at least 5 minutes to avoid later chlorate formation (otherwise it could explode!)
- Add ozone for 240 seconds, then ultrasonically activated for 3 minutes.

To avoid chlorate formation:

1. The higher the pH the less chlorate (ClO_3-) formation we will have.
2. H_2O_2 by itself is a weak oxidant, but it has a powerful synergistic effect when used with ozone. ClO_3- formation can be reduced by the addition of peroxide before ozonization and allowing sufficient time for the peroxide to react with the free chlorine. Add H_2O_2 for at least 5 minutes.
3. Decrease the temperature of the ozonization liquid to about 10 degrees C.
4. Buffer the solution pH to about 11 by adding NaOH.

We now have a different set of irrigants to use. These include:

- NaOCl
- EDTA
- Citric acid
- CHX
- Ozone

The question that remains for the near future is: which ECA technology will fit the needs of endodontic therapy in the best manner?_

_About the author

roots

Professor **Liviu Steier** has maintained a specialist private referral practice in Mayern, Germany, since 1985. He has completed a comprehensive postgraduate continuing education program in endodontics and is the visiting Professor at the University of Florence, Italy. He currently acts as lecturer at the Witten-Herdecke Dental School Germany, and also teaches at Queens University Belfast Dental School in Northern Ireland. He is also a specialist prosthodontist.

Liviu Steier, Dr.med.dent., Spezialist fuer Prothetik,
FICOI, FADFA, FIAG
20 Wimpole St.
London W1G 8GF
United Kingdom
E-mail: lsteier@gmail.com
www.drsteier.de

Transcription provided by:
Robert M. Kaufmann DMD MS (Endo)
Ste. 710, 500 Portage Ave.
Winnipeg, MB R3C 3X1 Canada

Fig. 3_Preop.
Fig. 4_Immediate postop.
Fig. 5_12-month recall with perfect healing.