Endodontic irrigants and irrigant delivery systems

Dr Gary Glassman

With the introduction of modern techniques, success rates of up to 98 per cent are being achieved.1 The ultimate goal of endodontic treatment per se is the prevention or treatment of apical periodontitis such that there is complete healing and an absence of infection,2 while the overall long-term goal is the placement of a definitive, clinically successful restoration and preservation of the tooth. For these to be achieved, appropriate instrumentation, irrigation, decontamination and root canal obturation must occur, as well as attainment of a coronal seal.

There is evidence that apical periodontitis is a biofilm-induced disease.3 A biofilm is an aggregate of microorganisms in which cells adhere to each other and/or to a surface. These adherent cells are frequently embedded within a self-produced matrix of extracellular polymeric substance. The presence of microorganisms embedded in a biofilm and growing in the root canal system is a key factor for the development of periapical lesions.4,5

Additionally, the root canal system has a complex anatomy that consists of arborisations, isthmuses and cul-de-sacs that harbour organic tissue and bacterial contaminants (Fig. 1).6

The challenge for successful endodontic treatment has always been the removal of vital and necrotic remnants of pulp tissue, debris generated during instrumentation, the dentine smear layer, micro-organisms, and micro-toxins from the root canal system.7

Even with the use of rotary instrumentation, the nickel-titanium instruments currently available only act on the central body of the root canal, resulting in a reliance on irrigation to clean beyond what may be achieved by these instruments.8

In addition, Enterococcus faecalis and Actinomyces prevent or treatment of apical periodontitis such as Actinomyces israelii - which are both implicated in endodontic infections and in endodontic failure - penetrate deep into dentinal tubules, making their removal through mechanical instrumentation impossible.9,10 Finally, E. faecalis commonly expresses multistres resistance,11,12 complicating treatment.

Therefore, a suitable irrigant and irrigant delivery system are essential for efficient irrigation and the success of endodontic treatment.13 Root canal irrigants must not only be effective for dissolution of the organic of the dental pulp, but also effectively eliminate bacterial contamination and remove the smear layer - the organic and inorganic layer that is created on the wall of the root canal during instrumentation. The ability to deliver irrigants to the root canal terminus in a safe manner without causing harm to the patient is as important as the efficiency of those irrigants.

Over the years, many irrigants and irrigant delivery systems have been tried in order to achieve tissue dissolution and bacterial decontamination. The desired attributes of a root canal irrigant include the ability to dissolve necrotic and pulpal tissue, bacterial decontamination and a broad antimicrobial spectrum, the ability to enter deep into the dentinal tubules, biocompatibility and lack of toxicity, the ability to dissolve inorganic material and remove the smear layer, ease of use, and moderate cost.

As mentioned above, root canal irrigants currently in use include hydrogen peroxide, NaOCl, EDTA, alcohol and chlorhexidine gluconate. Chlorhexidine gluconate offers a wide antimicrobial spectrum, the main bacteria associated with endodontic infections (E. faecalis and A. israelii) are sensitive to it, and it is biocompatible, with no tissue toxicity to the periapical or surrounding tissue.16

Chlorhexidine gluconate, however, lacks the ability to dissolve necrotic tissue, which limits its usefulness. Hydrogen peroxide as a canal irrigant helps to remove debris by the physical act of irrigation, as well as through effervescing of the solution. However, while an effective anti-bacterial irrigant, hydrogen peroxide does not dissolve necrotic intra-canal tissue and exhibits toxicity to the surrounding tissue. Cases of tissue damage and facial nerve damage have been reported following use of hydrogen peroxide as a root canal irrigant.17 Alcohol-based canal irrigants have antimicrobial activity too, but do not dissolve necrotic tissue.18

The irrigant that satisfies most of the requirements for a root canal irrigant is NaOCl.19 It has the unique ability to dissolve necrotic tissue and the organic components of the smear layer.20,21 It also kills sessile endodontic pathogens organised in a biofilm.22,23 There is as other root canal irrigant that can meet all these requirements, even with the use of methods such as lowering the pH,24,25 increasing the temperature,26–28 or adding surfactants to increase the wetting efficacy of the irrigant.29,30

However, although NaOCl appears to be the most desirable single endodontic irrigant, it cannot dissolve inorganic dentinal particles and thus cannot prevent the formation of a smear layer during instrumentation.31

Calculations hindering mechanical preparation are frequently encountered in the root canal system, further complicating treatment. Demineralising agents such as EDTA have therefore been recommended as adjuncts in root canal therapy.32–34 Thus, in contemporary endodontic practice, dual irrigants such as NaOCl with EDTA are often used as initial and final rinses to circumvent the shortcomings of a single irrigant.35–38 These irrigants must be brought into direct contact with the entire canal wall surfaces for effective action.39–41,42 particularly in the apical portions of small root canals.43

The combination of NaOCl and EDTA has been used worldwide for antisepsis of root canal systems. The concentration of NaOCl used for root canal irrigation ranges from 2.5 to six per cent, depending on the country and local regulations; it has been shown, however, that tissue hydrolysis is greater at the...

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**Fig. 1 Root canal complex.** (Image courtesy of Dr Ronaldo Orinoluwa Zapata, Brazil.)

**Table 1**

<table>
<thead>
<tr>
<th>Endodontic irrigant</th>
<th>Attributes</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaOCl</td>
<td>Effective dissolution, broad antimicrobial spectrum</td>
<td>High toxicity, irritant to tissue</td>
</tr>
<tr>
<td>EDTA</td>
<td>Biocompatible, effective for dissolving organic material</td>
<td>May not penetrate deep into dentinal tubules</td>
</tr>
<tr>
<td>Chlorhexidine gluconate</td>
<td>Antimicrobial activity</td>
<td>Limited ability to dissolve necrotic tissue</td>
</tr>
<tr>
<td>Hydrogen peroxide</td>
<td>Physical act of irrigation, effervescing</td>
<td>May not dissolve necrotic tissue</td>
</tr>
<tr>
<td>Alcohol</td>
<td>Antimicrobial activity</td>
<td>Limited ability to dissolve necrotic tissue</td>
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**Reference**

higher end of the range, as demonstrated in a study by Hand et al. comparing 2.5 and 5.25 per cent NaOCl. The higher concentration may also favour superior microbiological outcomes. NaOCl has a broad antimicrobial spectrum, including but not limited to E. faecalis. NaOCl is superior among irrigants and techniques that dissolve organic matter. EDTA is a chelating agent that aids in smear layer removal and increases dentine permeability, which will allow further irrigation with NaOCl to penetrate deep into the dentinal tubules.

General safety precautions
Regardless of which irrigant and irrigation system is employed, and particularly if an irrigant with tissue toxicity is used, there are several general precautions that must be followed. A rubber dam must be used and a good seal obtained to ensure that no irrigant can spill from the pulp chamber into the oral cavity. If deep caries or a fracture is present adjacent to the rubber dam on the tooth being isolated, a temporary sealing material must be used prior to performing the procedure to ensure a good rubber dam seal. It is also important to protect the patient’s eyes with safety glasses and protect clothing from irrigant splatter or spill.

It is very important to note that while NaOCl has unique properties that satisfy most requirements for a root canal irrigant, it also exhibits tissue toxicity that can result in damage to the adjacent tissue, including nerve damage should NaOCl incidents occur during canal irrigation. Furthermore, Salzgeber reported in the 1970s that apical extrusion of an endodontic irrigant routinely occurred in vivo. This highlights the importance of using devices and techniques that minimise or prevent this. NaOCl incidents are discussed later in this article.

Irrigant delivery systems
Root canal irrigation systems can be divided into two categories: manual agitation techniques and machine-assisted agitation techniques. Manual irrigation includes positive-pressure irrigation, which is commonly performed with a syringe and a side-ventured needle. Machine-assisted irrigation techniques include sonic and ultrasonic, as well as newer systems such as the EndoVac (SybronEndo), which delivers apical negative-pressure irrigation, the plastic rotary F-File (Plastic Endo), the Vihringe (Vihringe), the Rinsendo (Air Techniques), and the EndoActivator (DRNTSPL Tulsa Dental Specialties).

Two important factors that should be considered during the process of irrigation are whether the irrigation system can deliver the irrigant to the whole extent of the root canal system, particularly to the apical third, and whether the irrigant is capable of removing debris from the apical third, and isthmuses. When evaluating irrigation of the apical third, the phenomenon of apical vapour lock should be considered.

Apical vapour lock
Since roots are surrounded by the periodontium, and unless the root canal foramen is open, the root canal behaves like a close-ended channel. This produces an apical vapour lock that resists displacement during instrumentation and final irrigation, thus preventing the flow of irrigant into the apical region and adequate debridement of the root canal system. Apical vapour lock also results in gas entrapment at the apical third. During irrigation, NaOCl reacts with organic tissue in the root canal system, and the resulting hydrolysis liberates abundant quantities of ammonia and carbon dioxide. This gaseous mixture is trapped in the apical region and quickly forms a column of gas into which further fluid penetration is impossible. Extension of instruments into this vapour lock does not reduce or remove the gas bubble, just as it does not enable adequate flow of irrigant.

The phenomenon of apical vapour lock has been confirmed in studies in which roots were embedded in a polylinylsuloxide impregnation material to restrict fluid flow through the apical foramen, simulating a close-ended channel. The result in these studies was incomplete debridement of the apical part of the canal walls with the use of a positive-pressure syringe delivery technique. Micro-CT scanning and histological tests conducted by Tay et al. have also confirmed the presence of apical vapour lock. In fact, studies conducted without ensuring a close-ended channel cannot be regarded as conclusive on the efficacy of irrigants and the
Ultrasoundics - Ultrasonic energy produces higher frequencies than sonic energy but low amplitudes, oscillating at frequencies of 25,000kHz. Two types of ultrasonic irrigation are available. The first type is simultaneous ultrasonic instrumentation and irrigation, and the second type is referred to as passive ultrasonic irrigation operating without simultaneous irrigation (PUI). The literature indicates that it is more advantageous to apply ultrasonics after completion of canal preparation rather than as an alternative to conventional instrumentation.

PUI irrigation allows energy to be transmitted from an oscillating file or smooth wire to the irrigant in the root canal by means of ultrasonic waves. There is consensus that PUI is more effective than syringe needle irrigation at removing pulpal tissue remnants and dentine debris. This may be due to the much higher velocity and volume of irrigation flow that are created in the canal during ultrasonic irrigation. PUI has been shown to remove the smear layer; there is a large body of evidence with different concentrations of NaOCl. In addition, numerous investigations have demonstrated that the use of PUI after hand or rotary instrumentation results in a significant reduction in the number of bacteria, or achieves significantly better results than syringe needle irrigation.

Studies have demonstrated that effective delivery of irrigants into apical canals is compromised by a clean apical third in sealed root canals. In a number of studies investigators were unable to demonstrate that ultrasonic irrigation allows transport of an irrigant into the apical third of the root canal system. Fluid exchange and debris displacement were minimal. Equally important to his primary findings, Chow set forth an imitable paradigm for endodontic irrigation: “For the solution to be mechanically effective in removing all the particles, it has to: (a) reach the apex; (b) create a current (force); and (c) carry the particles away.” The apical vapour lock and consideration for the patient’s safety have always prevented the thorough cleaning of the apical 3mm. It is critically important to determine which irrigation system will effectively irrigate the apical third, as well as isthmiuses and lateral canals and in a safe manner that prevents the extrusion of irrigant.

Manual agitation techniques
By far the most common and conventional set of irrigation techniques, manual irrigation involves dispensing of an irrigant into a canal through needles/cannulae of variable gauges, either passively or with agitation by moving the needle up and down the canal space without binding it on the canal walls. This allows good control of needle depth and the volume of irrigant that is flushed through the canal. However, the closer the needle tip is positioned to the apical tissue, the greater the chance of apical extrusion of the irrigant. This must be avoided, were NaOCl to extrude past the apex, a catastrophic accident could occur.

Manual-dynamic irrigation
Manual-dynamic irrigation involves gently moving a well-fitting gutta-percha master cone up and down in short 2-3mm strokes within an instrumented canal, thereby producing a hydrodynamic effect and significant irrigant exchange. Recent studies have shown that this irrigation technique is significantly more effective than automated-dynamic irrigation and static irrigation.

Machine-assisted agitation systems
Sonic irrigation - Sonic activation has been shown to be an effective method for disinfecting root canals, operating at frequencies of 1-6kHz. There are several sonic irrigation devices on the market. The Vibringe allows delivery and sonic-activation of the irrigating solution in one step. It employs a two-piece syringe with a rechargeable battery. The irrigant is sonically activated, as is the needle that attaches to the syringe. The EndoActivator is a more recently introduced sonically driven canal irrigation system. It consists of a portable handpiece and three types of disposable polymer tips of different sizes. The EndoActivator has been reported to effectively clean debris from lateral canals, remove the smear layer, and dislodge clumps of biofilm within the curved canals of molar teeth.

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to the apical third can be enhanced by using ultrasonic and sonic devices that demonstrate acoustic micro-streaming and cavitation.44–46 Acoustic micro-streaming is defined as the movement of fluids along cell membranes, which occurs as a result of the alternating negative and positive mechanical pressure changes within the tissue. Cavitation is defined as the formation and collapse of microbubbles or cavities in a fluid.

The Apical Vapour Lock theory was clinically demonstrated to also include the middle third by Vera: “The mixture of gases is originally trapped in the apical third, but then it might grow quickly by the nucleation of the smaller bubbles, forming a gas column that might only impede penetration of the irrigant into the apical third but also push it coronally after it has been delivered into the canal.”47,48 Moreover, Munoz demonstrated that both passive ultrasonic irrigation (PUI) and EndoVac are more effective than the EndoVac Microcannula with an acoustic needle in delivering irrigant to WL of root canals.49

This begs the efficacy question. Two recently published studies examined this issue with both systems by testing their ability to eliminate microorganisms during clinical treatment from infected root canal systems.50 Paiva found that after a supplementary irrigation procedure using PI1 with NaOCl that 25% of the samples produced positive cultures. Cohenca’s study examining the efficacy of the EndoVac found no microbial growth either after post instrumentation irrigation or at the one-week subclinical appointment.

When questioning these divergent results one must remember that microbial hydrolysis via NaOCl can or should be excluded as the NaOCl incident is rare,107 the risk of a NaOCl incident. The EndoVac can or should be excluded as the NaOCl incident is rare,107 the risk of a NaOCl incident. The NaOCl incident is still uncertain. Although the exact aetiology of the NaOCl accident is still uncertain, based on the evidence from actual incidents, it is likely that the associated tissue trauma, it would appear that an intravenous injection may be the cause. The clinical significance of which is paramount for minimizing clinical trauma, it could only have occurred if the NaOCl had been introduced intravenously to a vein close to the root apex through which extravasion of cavity fluid and the NaOCl accident occurred. The irrigant then found its way into the venous complex. This would require positive pressure apical negative pressure to exceed venous pressure (10mg of Hg). In one in vitro study, which used a positive-pressure needle irrigation technique to mimic clinical conditions and techniques, the apical pressure generated was found to be eight times higher than the normal venous pressure.108

This does not imply that NaOCl can or should be excluded as an endodontic irrigant; in fact, its use is critical, as has been discussed in this article. What this does imply is that it must be delivered safely.

Safety first
In order to compare the safety of different intra-canal irrigation delivery devices, an in vitro test was conducted using the worst-case scenario of apical extravulsion, with neutral atmospheric pressure and an open apex.109 The study concluded that the Endo-Vac did not extrude irrigant after deep intra-canal delivery and suctioning of the irrigant from the chamber to full working length, whereas other devices did. The EndoActivator extruded only a very small volume of irrigant, the clinical significance of which is not known.

Mitchell and Baumgartner tested irrigant (NaOCl) extravulsion to the pulp chamber and sphenopalatine ganglion using an impermeable agarose gel.110 Significant less extravulsion occurred using the EndoVac system compared with periradicular needle irrigation. A well-controlled study by Godinom et al. found that patients experienced less post-operative pain with the EndoVac system compared with the conventional needle irrigation. The associated sequelae of NaOCl exposure have been reported to include threatening airway obstructions,46–47 facial disfigurement requiring multiple corrective surgical procedures,46 permanent palatal perforation and irreversible facial muscle control,58–60 and - the less significant consequence - tooth loss.111

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In vitro and in vivo studies have demonstrated greater removal of debris from the apical walls and a statistically cleaner result using apical negative-pressure irrigation in closed endodontal systems with sealed apices. In an in vivo study of 22 teeth by Siu and Baumgartner, less debris remained at 1.5 mm from working length using apical negative pressure compared to use of traditional needle irrigation, while Shim et al. found in an in vitro study of 69 teeth comparing traditional needle irrigation with apical negative pressure that these methods both resulted in clean root canals, but that apical negative pressure resulted in less debris remaining at 1.5 and 3.5 mm from working length.117,118

When comparing root canal debridement using manual-dynamic agitation or the EndoVac for final irrigation in a closed system and an open system, it was found that the presence of a sealed apical foramen adversely affected debridement efficacy when manual-dynamic agitation was used, but did not adversely affect results when the EndoVac was used. Apical negative-pressure irrigation is an effective method to overcome the fluid-dynamic challenges inherent in closed root canal systems.117

Microbial control
Hockett et al. tested the ability of apical negative pressure to remove a thick biofilm of E. Faecalis, finding that these specimens rendered negative cultures obtained within 48 hours, while those irrigated using traditional positive-pressure irrigation were positive at 48 hours.118

One study found that apical negative-pressure irrigation resulted in similar bacterial reduction to use of apical positive-pressure irrigation and a triple antibiotic in immature teeth.118 In a study comparing the use of apical positive-pressure irrigation and a triple antibiotic that has been utilised for pulpal regeneration/vascularisation in teeth with incompletely formed apices (Trimix = Cipro, Minocin, Flagyl) versus use of apical negative-pressure irrigation with NaOCl, it was found that the results were statistically equivalent for mineralised tissue formation and the repair process.119 Using apical negative pressure and NaOCl also avoids the risk of drug resistance, tooth discolouration, and allergic reactions.119,120

Conclusion
Since the dawn of contemporary endodontics, dentists have been straining NaOCl into the root canal space and then proceeding to place endodontic instruments down the canal in the belief that they were carrying the irrigant to the apical termination. Biological, scanning electron microscopy, light microscopy, and other studies have proven this belief to be in error. NaOCl reacts with organic material in the root canal and quickly forms micro-bubbles at the apical termination that coalesce into a single large apical vapour bubble with subsequent instrumentation. Since the apical vapour lock cannot be displaced via mechanical means, it prevents further NaOCl flow into the apical area. The safest method yet discovered to provide fresh NaOCl safely to the apical terminus to eliminate the apical vapour lock is to evacuate it via apical negative pressure. This method has also been proven to be safe because it always draws irrigants to the source via suction - down the canal and simultaneously away from the apical tissue in abundant quantities.120 When the proper irrigating agents are delivered safely to the full extent of the root canal terminus, thereby removing 100 per cent of organic tissue and 100 per cent of the microbial contaminants, success in endodontic treatment may be taken to levels never seen before.121

Editorial note: A complete list of references is available from the publisher. This article has been reprinted in part from G. Glassman, Safety and Efficacy Considerations in Endodontic Irrigation (Penwell, January 2011).

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**About the author**

Dr Gary Glassman graduated from the University of Toronto Faculty of Dentistry in 1984 and graduated from the Endodontology Program at Temple University in 1987, where he received the Louis I. Grossman Study Club Award for academic and clinical presentation. He is an associate professor and author of numerous publications, he lectures globally on endodontics and is on the staff at the University of Toronto Faculty of Dentistry in the Graduate Department of Endodontics. He is a fellow of the Royal College of Dentists of Canada, and the endodontic editor for the Oral Health journal. He maintains a private practice, Endodontic Specialists, in Toronto, Ontario, Canada. He can be reached through his website, www.rootcanals.ca

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Endodontic dentistry in daily practice use (16,000 cases)

Dr. Robert Teeuwen - A Practitioner of Endo Techniques according to Sargenti

How did you learn about N2? During my years of study at the University of Bonn, Germany (May 1959 – February 1965) N2 was the preferred root canal filling material of the dental clinic. When assisting in my father’s dental practice I used to work with N2 as well – occasionally replaced by Endomethasone, Riebler and Diaket.

Since when have you been familiar with the method developed by Dr. Sargenti? I first learned about the Sargenti method in the years 1968 – 1970. This method convinced me as it is efficient and time-saving, which was very convenient for me as I had opened my own dental practice in July 1969 and never knew how to cope with the heavy patient traffic. So I was forced to think about measures to work efficiently – not only in endodontics. From April 1972 I worked with an assistant according to my instructions. Since the day...
of opening my practice, all of mine and the assistant’s dental treatments have been recorded. All of these practice diaries do still exist, however, the patient’s file cards are no longer complete. So I was able to count the number of endodontic treatments.

How many root canal treatments have you done so far? I did 16,678 endodontic treatments with N2 in permanent teeth from 7/1969 to 12/2005. My assistants made it to 10,456.

N2 endodontic treatments in the time from 04/1972 to 12/2001. For comparison: In his book “Endodontic Therapy” (5th ed. 1998), the renowned endodontist Weine reports about 18,500 endodontic treatments he had personally done.

Only 22 (five done by myself, 17 by an assistant) out of more than 8,800 computerised vital endodontic treatments between the years 1985 – 1999 required more than one appointment. I haven’t counted thousands of vital amputations and endodontic treatments of deciduous teeth.

How are your experiences with these cases? Several times I tried to treat deciduous teeth with Ca (OH)2. I judged the subsequent pain rate as being too high. It applies to all (dental) medical disciplines that the practitioner virtually loses face the more a patient has to see the doctor because of unsolved problems (pain after endodontic treatment, surgery, pressure marks).

How were you convinced to use N2 permanently? If not overfilled, a vital endodontic treatment with N2 never ends up in pain, including endodontic treatment of deciduous teeth.

How did you get into contact with Dr. Sargenti? I wanted to meet Dr. Sargenti whilst on vacation in Switzerland in 1989. He gave me quite a short shrift at his doorstep. In the year 1990, it was Dr. Sargenti who asked me for contact. He had suffered from a stroke and was in need of help. He knew that I had done a lot of endodontic therapy.

Fig 1 1988: X-ray control after 13 years, NAD

Fig 2 1996: X-ray control after 24 years

Fig 3 1998: Tooth 16 reimplanted with existing parallella

Fig 4 2003: X-ray control after 13 years, NAD

Fig 5 1996: X-ray control after 13 years, NAD

Fig 6 2007: X-ray control after 24 years
What does the N2 method do?  I also know surgeons who use my fistulation after 20 minutes. Treatment belonging here.

done efficiently without much apectomy; the other teeth were of the cases, gangrenous teeth was only done in exceptional cases, so we did not know what we were doing. Consequently, frequent failures due to root filling quality could be observed after years. At least this proved that the Sargenti method does not necessarily protect against failures due to poor root filling quality. In case of heavily overfilling, I prophylactically made a “Schröder Airation” (artificial fistulation). In most of the cases, gangrenous teeth could also be treated in one appointment. In case of short root filling, I finished treatment by apectomy; the other teeth were treated by trephination.

Whether apectomy or trephination – treatment has to be done efficiently without much fumbling to avoid subsequent problems. Acute exacerbations do very rarely occur after apectomy/trephination. I occasionally treated a “via falsa” with percussion and N2 leakage into the bone successfully by fistulation as well. I use the expression “occasionally” as this happened only very rarely, thus there had been little chance to do the therapy. Basically I regard the perforation area as an artificial foramen, a foramen not belonging here.

In few cases, I tried Diaket out as root filling material with following fistulation. Treatment is also successful with Diaket, however, I mind that it doesn’t pour off the lento the perfect way N2 does. It hardens as fast as N2, though. Root filling was followed by a visible apec- tomy/fistulation after 20 minutes. I also know surgeons who use either N2 or Diaket.

What does the N2 method comprise? • No canal rinsing • Use of the reamer as sole root canal instrument

Rubberdam for safety’s sake for manual manipulations only • Use of the strongly anti microbial N2 as root canal filling material (the powder contains five per cent formaldehyde, EU approval as medical device 6/1996) • Root canal treatment in one appointment is the goal (no problem in vital teeth, in non vital teeth with reservation – in the latter case definitely complete reaming during the same appointment). Alternatively in one appointment finished by “Schröder Airation”. According to Sargenti, the “Schröder Airation” comprises a wide treat ment spectrum: pain prophylax is during root canal treatment of non-vital teeth in one ap pointment plus after overfilling of vital teeth roots, apart from that for pain therapy • According to Sargenti, point condensation of the root filling is not necessary, however, it looks better on X-ray.

What do you think about the frequently discussed ingredient formaldehyde: Systemic distribution in the body ac cording to literature? There is only an ambivalent an swer to this question. The Block study with dogs as test animals circulates in literature. First of all, it has to be made clear that results from animal experi ments cannot simply be adopt ed for humans due to different metabolisms. So formaldehyde features different half-lives in different animal species. In hu mans, half-life of formaldehyde amounts to 1 – 1.5 minutes. In an N2 court hearing in the US, the former leading US toxicologist Brent stated that the results of the Block study had been misinterpreted. Due to the short half-life, formaldehyde had no longer bonded to marker C14. Correctly, the systemic distri bution of C14 in the organs had been detected, however no for maldehyde. At this point, I also wish to criticise laboratory tests (in vitro). An adoption of such results has to be judged skepti cally as the enzymes of the living organ is missing.

Have you ever experienced intolerances or allergic reac tions to N2 in your practice? I have never seen an immediate or time-delayed allergic reaction although, to my knowledge, five of my patients, who have been provided with N2 root fill ings, actually do suffer from for maldehyde allergy. Surely the (not verified) estimated num ber of unreported cases might have been much higher. As can be learned from literature, aller gies against dental material do occur extremely rarely. In addition, self-reported cases do not necessarily stand up to scientific examinations.

Is there any evidence of cancerogenity or mutagenity from your point of view? Cancerogenity or mutagenicity could not have been proved by now. However, formaldehyde has been classified as human cancerogene some years ago, i.e. for pharyngeal tumor after consumption of a high dosage. Like in many cases, the same rule must be obeyed: Toxicity depends on the dosage. Still the statement on formaldehyde of the German Federal Medical Association (Dr. Arzthel 1987; 84, issue 15; 8.2017 – 82112) comprising that exceeding of a threshold value is the pre condition for cancerogenity keeps existing.