

Ozone in Dentistry: What Dentists Should Know About This Gas?

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Introduction

Many centuries ago, the Greeks noticed a peculiar odor in air that followed lightning and thunderstorm and described it 'ozein' meaning 'to smell' (Asimov, 1964). In 1839, C. F. Schoenbein (Mordecai, 2001), a professor of chemistry at Besal, discovered a gas that was produced by electric discharges in air. He noted its strong oxidizing property, which was by then known as ozone. In his experiment the fetid smell of a highly putrefied piece of flesh was destroyed by ozone gas. He concluded that ozone was a powerful oxidant as well as a disinfectant (Bocci, 2004). Soon after that, the first ozone generator was constructed in Berlin, Germany. During the same period Nikola Tesla, a physicist, patented his ozone generator and later formed the Tesla Ozone Company (Patents of Nikola Tesla 'Apparatus of producing Ozone' Patent Number 568,177 September 22, 1886). In the early 1900's ozone was being used for drinking water treatment and ozone plants were built in Monaco and Nice, France (Kerwin, 2005).

Today ozone is known as a naturally occurring allotrope of oxygen. It can be present as a gas, liquid or dissolved in a liquid (Horvath *et al.*, 1985). The popular knowledge about ozone is almost exclusively relating to its gaseous state. For example the ozone-depleting layer in the troposphere is a gaseous layer, which protects us from the sun's harmful ultra violet radiation. The gaseous ozone is considered to be one of the most important urban air pollutants (WHO, 2003). In nature it is produced by the combination of the sun's ultra-violet rays and oxygen in air or by the corona discharge after a thunderstorm. This concept is applied

in producing ozone from ozone generators. A corona discharge ozone generator produces an electric discharge simulating the lightning, which converts oxygen to ozone. Ultra-violet ozone generators utilize ultra-violet rays simulating the UV radiation of sun in producing ozone (Smith *et al.*, 1955; Dohan *et al.*, 1987). Newer generators have been developed to produce ozonated water (ozone dissolved in water) using different methods like electro-conductive diamond electrodes (Sekido, 2008).

Ozone Chemistry and Toxicity

Ozone is a pale blue gas with a strong odour. It is deep blue when in liquid form and is strongly magnetic. Its chemical formula is O₃ and has three atoms in each molecule. Being a powerful oxidant, it reacts with almost all biological substances. It is capable of drawing electrons from a source, and in the process decreases the oxidation state of at least one of its oxygen atoms (Rideal, 1920).

This oxidative capacity is accepted to be the cause of its toxic effect. In the human biological system the toxicity of ozone is the result of amino acids or unsaturated fatty acid oxidation to fatty acid peroxidase in tissues (Menzel, 1984). It has been reported that a short duration of ozone inhalation at low concentrations can cause occasional discomfort, headache, dryness of throat and nasal irritation. Exposure to higher concentrations can cause delayed lung oedema, frontal headache, substernal pain and anorexia. More severe exposures can produce dyspnea, cough, tachycardia, vertigo, lowering of blood pressure, severe cramping and chest pain. It has

been estimated that exposure to ozone for 30 minutes at a concentration of 50ppm can be fatal (Gottschalk *et al.*, 2000). The increased level of ozone in air had been associated with the increased respiratory admissions in hospitals (Bates, 1989). Toxicity following controlled human exposure to ozone has not been reported due to ethical considerations. Earlier studies have shown that animals exposed to certain concentrations of ozone had damaged respiratory tracts and epithelial injury (Pino *et al.*, 1992). The effect was seen at concentrations as high as 0.5 ppm following a two-hour exposure (Stephens *et al.*, 1974a). In monkeys the inflammatory response was seen as early as four hours after exposure to 0.8 ppm of ozone (Castleman *et al.*, 1980). Exposure to 0.50 ppm of ozone for 2-3 hours can also cause significant haematological changes (Buckley *et al.*, 1975). The time required for ozone exposure to result in morphological changes in rats was two hours (Stephens *et al.*, 1974b). According to the National Ambient Air quality standards the minimal exposure to ozone has been set at 0.12 ppm for a maximum of one hour in a year (Jakab *et al.*, 1995).

Applications of Ozone

The applications of ozone have been based on its powerful oxidizing nature. It has been used for disinfection of drinking water, purification of ground water and industrial wastewaters (Moriwa, 1995). Compared to chlorine, the concentration of ozone required to purify the drinking water is much less (Hoigne, 1998). Ozone purification has no side effects such as taste, odour or by-products which are often observed with other disinfecting agents (Toricelli, 1959).

The oxidizing property of ozone is applicable in paper, food, pharmaceutical, semiconductor industries, medicine and dentistry. Ozone possesses the ability to reduce the microbial load and to oxidize toxic inorganic compounds which makes it very useful in the preservation and extension of the food shelf life (Kim *et al.*, 1999). In the pharmaceutical industry ozone has been used to produce ultrapure water in the manufacturing process (Gurley, 1985).

Medicinal application of ozone dates back to World War I, when ozone gas was used for treating post-traumatic gangrene for German soldiers (Bocci, 2005). In the field of medicine, under prescribed guidelines, ozone therapy has been used to treat chronic infectious, pulmonary, hematological, macular degenerative and peripheral obstructive arterial diseases (Bocci *et al.*, 2009). Medical ozone generators are equipped with a photometer to deliver

precise concentration of ozone, which is then mixed with pure oxygen and exposed to human blood. This is called ozonated autohemotherapy and was first developed by the physician Hans Wolff (Bocci *et al.*, 2009). Cancer and chronically dialyzed patients have been reported to show an improvement in quality of life with ozonated autohemotherapy (Tylicki *et al.*, 2001; Bocci, 2006).

Applications of Ozone in Dentistry

A Swiss dentist E. A. Fisch (1899-1966) was the first to use ozone to treat pulpitis (Bocci, 2005). Recently ozone has been evaluated and studied with great interest in the field of dentistry. Thus far, studies with ozone gas and ozonated water have led to interesting results that call for more in-depth knowledge (Bocci *et al.*, 2009). Both ozone and ozonated water have a similar antimicrobial activity against bacteria, fungi, protozoa and viruses. The bacterial cells in the vegetative state were found to be extremely sensitive to low concentration of ozonated water, whereas their spores were less sensitive (Broadwater *et al.*, 1973).

Ozonated water is also effective in inhibiting bacterial growth in biofilms. Treatment of experimental plaque with ozonated water has shown a significant reduction in the number of viable *Streptococcus mutans*. The effectiveness of ozonated water on human plaque biofilm is comparable to other commonly used antimicrobial agents such as povidone iodine and benzylthionium chloride (Nagayoshi *et al.*, 2004). It has also been used to clean and disinfect dentures and in the treatment of dental unit water lines (Oizumim *et al.*, 1998; Pankhurst *et al.*, 1998).

Treatment of Caries and Disinfection

Ozone disinfects by rapidly rupturing the cell membrane of bacteria. It is generally accepted that it induces oxidation of the cell wall and cytoplasmic membranes thereby destroying the cell microorganism. Bacteria suspended in Phosphate Buffer Saline are completely inactivated after a mere 15 seconds exposure with ozone gas. Likewise, viruses suspended in fluid low in organic material are also rapidly inactivated with ozone gas (Burleson *et al.*, 1975). Suspensions of *Actinomyces naeslundii*, *Lactobacilli casei* and *Streptococcus mutans* in salt buffer, when exposed to ozone gas delivered by Healozone[®] were completely killed in 60 seconds (Johansson *et al.*, 2009). Scanning electron microscopic studies on *streptococcus mutans* cells

treated with ozonated water had holes in its membrane, which suggests that its bactericidal activity is causing structural disorder in the cytoplasmic membrane (Nagayoshi *et al.*, 2004).

Primary root caries lesions (PRCL) are quite common in older patients. They present a very complex etiology and require a multidisciplinary approach for their management (Shay, 1997). *Streptococcus mutans*, lactobacillus and actinomyces are accepted to be the initiating causative microorganisms of PRCL's (Beighton *et al.*, 1993). Ozone gas has been used to inactivate these microorganisms through specifically made ozone delivery system like HealOzone[®] and Ozicure. The HealOzone[®] system avoids excess of ozone exposure and its subsequent toxic effects in the oral cavity and the respiratory tract (Millar, 2007). The tooth lesion is exposed for 10 to 20 seconds of ozone gas that passes through a suction system. The lesion-bearing tooth is enclosed in a tightly fitting cup and a granular activated carbon filter prevent any ozone from spilling and remaining in the oral cavity after being in contact with the lesion. It is claimed that ozone treatment through this system reduces most microorganisms and can arrest the progress of the lesion and perhaps allow remineralization of tooth structure to occur (Baysan and Lynch, 2004). It is being considered as a potentially effective alternative to the conventional 'drilling and filling' of PRCL's. HealOzone[®] has also been used to treat sensitive cervical caries and dentine hypersensitivity with some success (Dähnhardt *et al.*, 2008; Azarpazhooh *et al.*, 2009). In general, it is accepted that its application to tooth surface does not affect the physical properties of enamel or micro-leakage and penetration proportion of flowable composite resins (Celiberti *et al.*, 2006; Dukić *et al.*, 2009).

Separate studies indicated that three months after HealOzone[®] application to non-cavitated initial occlusal fissure caries showed reduced caries progression or caries reversal (Huth *et al.*, 2005). However, Rickard *et al.*'s (2004) review of HealOzone[®] results had different conclusions. They stated that due to the lack of reliable evidence and the risk of high bias in the studies, the effectiveness of HealOzone[®] remains unclear. A similar conclusion can be drawn from the study of McComb of University of Toronto (McComb, 2005). He quoted that "there is no reliable evidence that the application of ozone gas to the surface of decayed teeth stops or reverses the decay process". Furthermore, it is too early to consider this system to be more cost-effective than the current management of PRCL's and occlusal fissure caries (Brazzelli *et al.*, 2006). When used in

endodontics as an irrigant, ozone gas/ozonated water was not sufficient to disinfect the human root canals (Estrela *et al.*, 2007; Virtej *et al.*, 2007). Nevertheless, the fact that ozone inactivates cariogenic bacteria remains accepted.

Denture Cleaning

Dentures tend to become unsanitary and emit unpleasant odour when used in the oral cavity. This is attributed to the accumulation of denture plaque, which has a microbial composition similar to dental plaque except for an increased count of candidal species (Budtz-Jorgensen and Theilade, 1983; Theilade *et al.*, 1983). Candida has been associated with denture related stomatitis since 1936 (Cahn, 1936). The swallowing or aspiration of microorganisms from denture plaque exposes denture wearers, particularly the medically immuno-compromised individuals to infections. Various materials are used to clean and disinfect denture plaque. Since ozone has a strong disinfecting and deodorizing property it has been tested in high concentrations for disinfecting dentures, particularly from the candidal species (Arita *et al.*, 2005). Ozone bubbles decrease the candida albicans in denture plaque to 1/10 after 30 minutes of exposure at 10 ppm (Murakami *et al.*, 1996).

Treatment of Dental Unit Waterlines

Dental unit asepsis and patient's exposure to contaminants from the dental unit waterline is a matter of concern for dentists as well as patients. Stagnation of water in the dental unit waterline causes the formation of biofilms on its internal surfaces. Biofilm harbor microbes that fluctuate and can reach high levels (Williams *et al.*, 1995).

Both mechanical and chemical approaches are used to minimize the risk arising from this biofilm. Anti-retraction valves, filtration and flushing are advised in combination with chemical disinfectants (Franco *et al.*, 2005). Agents such as bleach, glutaraldehyde, iodophors, chlorhexidine and essential oil mouthwashes are among the common chemical agents used for disinfection. Potential toxicities may exist with some of these agents, while some interact or interfere with materials and equipments in the dental office. Glutaraldehyde, for example, can be toxic if used in excess. Chlorine, on the other hand, has the tendency to corrode metal while concentrated mouth rinses may interfere with the physical properties of filling materials (Roberts *et al.*, 2000; Meiller *et al.*, 2004). Hence, a material of choice is still not available. Ozone has been tried by

introducing it continuously into the dental unit waterline while patients are being treated to maintain low levels of planktonic load throughout the treatment period (Pankhurst *et al.*, 1998). However, current information regarding ozone with regard to purification of dental unit waterline is scarce and limited.

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