Ozone - A Revolution in Dentistry

Historical uses of Ozone and rationale for the use of the HealOzone.

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Every dental practitioner is well aware of the patient's cliché, "I detest going to the dentist. Drilling hurts and I hate the sound," but few dental practitioners are aware of the alternative treatment for tooth decay. Instead of drilling and filling, a new alternative method is now available.

The "other" way to treat tooth decay is with the HealOzone® unit (KaVo GmbH, Germany). This new technology, the HealOzone® unit, uses well-documented properties of ozone gas. It is treats the potentially harmful dental cavities. The HealOzone® unit is a portable ozone generator. Designed especially for dental use and the treatment of intra-oral lesions of the hard and soft tissues, dental hospitals and general dental practice have been using it for several years. It involves no local anesthesia, no water spray no high volume suction, no noisy hand pieces and it is a very quick procedure. The patient and the general dental practitioner would undoubtedly prefer this option as it is painless, quick, and more pleasant for the patient. At the same time, it is an easy, efficient and very profitable alternative for the dental practitioner.

Ozone is a gas that is produced in the upper atmosphere as long as the sun shines. It is heavier than air and thus prone to gravity. As it falls towards the earth, it binds to any pollutant in the atmosphere that touches it, thereby cleaning the air. If ozone binds water molecules in water vapor in the atmosphere, it forms hydrogen peroxide, a component of rainwater. Even plants show why the cleaner rainwater allows them to grow better than tap water used in irrigation.

There are three ways to create ozone: The first is by lighting, which provides the wonderful fresh smell after a thunderstorm. The second is through waterfalls and crashing surf, which accounts for the energetic feeling and calm experienced near these sites. The third way is by photons from the sun breaking apart nitrous oxide, a pollutant formed by the combustion of hydrocarbons in the internal combustion engine. This type of ozone accumulates in smog due to temperature inversions and is a lung and eye irritant. This duality of ozone and its effects are the reasons why the media focuses on and why the healing property of ozone tends to be ignored.

One of the most common uses of ozone is for the treatment of water. Scientists and doctors studied the ozonation system at the Oudshoorn plant in Holland and later constructed a 19,000 M3/day (5 mgd) plant using ozonation for disinfection at Nice, France in the early 20th Century. Nice is often referred to as "the birthplace of ozonation for drinking-water treatment".

Ozone has a long history in research and medicine. In 1785, Van Marum noticed that air near his electrostatic machine acquired a characteristic odor when electric sparks were passed. In 1801, Cruickshank observed the same odor at the

anode during electrolysis of water. Finally, in 1840, Shonbein named the substance, which gave off this odour, ozone, from the Greek word "*ozein*"- to smell.

In 1857 Werner Von Siemens designed an ozone generator that has since greatly evolved. The cylindrical dielectric type makes up most of the commercially available ozone generators in use, and which has sometimes been called the "Siemens Type" ozone generator. Since the discovery of the benefits of ozone, many articles were published and the substance became useful in water purification, technology and medicine. In 1902, J.H.Clarke's "A Dictionary of Practical Materia Medica" London, described the successful use of ozonated water in treating anaemia, cancer, diabetes, influenza, morphine poisoning, cancer sores, strychnine poisoning and whooping cough.

In 1911, "A Working Manual of High Frequency Currents" was published by Dr. Noble Eberhart, MD. Dr. Eberhart, head of the Department of Physiologic Therapeutics at Loyola University, used ozone to treat tuberculosis, anaemia, chlorosis, tinnitus, whooping cough, asthma, bronchitis, hay fever, insomnia, pneumonia, diabetes, gout and syphilis. In 1913, the Eastern Association for Oxygen Therapy was formed by Dr. Blass and some German associates.

During World War 1, ozone was used to treat wounds, trench foot, gangrene and the effects of poison gas. Dr. Albert Wolff of Berlin also used ozone for treating colon cancer, cervical cancer and decubitis ulcers in 1915.

In 1920, Dr. Charles Neiswanger MD, the President of the Chicago Hospital College of Medicine, published "Electro Therapeutical Practice." Chapter 32 was entitled "Ozone as a Therapeutic Agent."

In 1926, Dr. Otto Warburg of the Kaiser Institute in Berlin announced that the cause of cancer is a lack of oxygen at the cellular level. Dr. Otto Warburg received the Nobel Prize for Medicine in 1931 and again in 1944.

In 1929, a book called "Ozone and Its Therapeutic Action" was published in the USA listing 114 diseases and how to treat them with ozone. Its authors were the heads of all the leading American hospitals.

The Swiss dentist Dr Edwin Fisch used ozone in medical practice before 1932, and introduced it to the German surgeon Erwin Payr who used it from that time on. Aubourg and Lacoste were French physicians using ozone insufflations from 1934 to 1938.

The use of ozone in the United States can be traced back to the 1940's. In 1948, Dr. William Turska of Oregon began using ozone with a machine he designed himself. In 1951, Dr. Turska wrote the article "Oxidation". He was the first to inject ozone into the portal vein, thereby reaching the liver (a technique that is no longer practiced).

From 1953, a German doctor, Hans Wolff, used ozone in his practice. He wrote the book "Medical Ozone," and trained many doctors in ozone therapy.

In 1957, Dr. J. Hansler patented an ozone generator that has formed the basis of the German expansion of ozone therapy over the last 35 years. Today over 7000 German doctors use ozone therapy daily.

In 1961, Hans Wolff introduced the techniques of major and minor autohemotherapy. In 1964 Spontaneous flocculation in ozone contact chambers led to France constructing an ozone plant to enhance particulate removal. In 1965 Scotland, United Kingdom, ozone was used for color control in surface water for the first time. At the same time, Swiss research lead to the use of ozone to oxidize micro pollutants such as phenolic compounds and several pesticides.

In 1977, Dr. Renate Viebahn provided a technical overview of ozone action in the body. In 1979, Dr. George Freibott began treating his first AIDS patient with ozone, and in 1980, Dr. Horst Kief reported success in treating AIDS with ozone. In 1987, Dr. Rilling and Dr. Viebahn published "The Use of Ozone in Medicine." In 1990, the Cubans reported their success in treating glaucoma, conjunctivitis and retinitis pigmentosa with ozone.

In 1978, a FDA report showed that 1.5 million people were hospitalized in the USA due to side effects from medication. On the other hand, medical ozone has been legally used in clinics worldwide on a daily basis since the 1940's. In Germany, ozone side effects are occasionally minor irritations that are caused by incorrect application and quickly disappear. This side effect rate is incredibly far lower than U.S. drug therapy side effect rates. Ozone, on the other hand, has been found to be an extremely safe medical therapy, free from side effects. In 1980, a study performed by the German Medical Society for Ozone Therapy. 644 therapists were asked about their 384,775 patients, comprising a total of 5,579,238 ozone treatments administered. There were only 40 cases of side effects, which were all operator/administrator caused, noted out of this number which represents the incredibly low rate of .000007%, and four fatalities. It is essential that Ozone gas should never be directly injected intravenously due to the potential for air emboli, which can be fatal. Ozone administered by other ways rather than intravenous gas delivery, is thus the safest medical therapy ever devised. Professor Velio Bocci from the University of Siena Italy has called for and has published excellent research objectively quantifying the therapeutic benefits of using Ozone (Bocci 1996, Bocci 1996, Bocci 1997, Bocci 1999, Bocci & Aldinucci 2004). In 1992, the Russians revealed their techniques of using ozone bubbled into brine to treat burn victims with astonishing results.

Ozone has played a significant role in the waste treatment process in the past and will continue to do so in the future. The utilization of ozone in industrial situations has a long and impressive history, one that pre-dates current environmental concerns.

When ozone is used to treat drinking water, it is effective in eliminating color, taste, and odor. Its competition, chlorine, which is used in many facilities as a disinfectant, has recently been found in scientific studies to have a tendency to create carcinogens as it breaks down. For this reason, there is increased pressure to reduce or eliminate chlorine as a primary disinfectant to water. Ozone is 150 times more powerful than chlorine and 3500 times faster acting. It eliminates harmful metals as well, by causing these metals to clump together which allow them to be large enough to filter out. Because of ozone's short life, it quickly converts to pure oxygen and thus adds much needed oxygen to the water. Since ozone water purification systems require no chemicals, they are healthier and very cost-effective in long-term applications.

After 125 years of usage, ozone therapy in medicine and various other fields is widely accepted in many nations around the world, including Germany, France, Italy, Russia, Romania, Czech Republic, Poland, Hungary, Bulgaria, Israel, Cuba, Japan, Mexico, and in some U.S. states.

Tooth decay is the second most common disease in the world. So-called modern dentists amputate more and more tooth material from their patients every day. This form of treatment forms the bulk of traditional dental care.

General Dental Practitioner's (GDP's) who work with in Socialised Dental Health Care Schemes around the world are super efficient at drilling and filling, or amputation therapies. After all, this is exactly what they were sure they knew the day they walked out of dental school. Taken across the world, this is a massive number of patients entering 'the repeat restoration cycle': Cavity preparation by substrate removal, restoring the lost substance by filling materials. This most common form of treatment, results in more extensive and costly treatment options in the future.

Dental surveys of oral health in the U.K. have revealed a reduction in the incidence and prevalence of dental caries in certain age groups (Nunn et al 2000). This is a positive finding, but there remain large areas of the country where dental diseases are out of control and continue to pose a major public health problem.

Parts of Wales and Ireland are known to have some of the worst dental health in Europe. It follows that in areas where dental disease occurs very often, dental fear and phobia are also common. Ignorance of dental health, diets rich in refined carbohydrates, sugar loaded soft drinks and consumption of great amounts of sticky treats are the norm in those areas. Even schools in affected areas ignore the health hazards of disease. Evidence to suggest the fizz in sodas could be associated with gastro-intestinal problems will hopefully start to limit its expansion into a population group that is naïve and prone to commercial marketing.

Every day some of these general dental practitioners come into contact with patients of all ages, with staggering levels of dental disease. Dental practitioners in these areas witness acute dento-alveolar abscesses, acute necrotising ulcerative gingivitis, pulpitis and broken down teeth, as well as fear and phobia towards dental treatment.

There is more than one diagnosis: The first is the old model of caries described as the loss of dental tissues as a process proceeding from the periphery to the centre, creating a crater in the hard tissues. If left untreated, these lesions proceed towards the blood supply system, and would lead to an infection in the bone. These lesions are easily detected visually or mechanically using a probe and radiography.

However, there is a new model of caries, the second type of caries. Caries starts at the enamel dentin junction (EDJ), as the consequence of bacterial penetration and colonisation via fissures, pores and fractures in the enamel surface of the tooth, which appears untouched. Demineralisation and proteolysis proceed into dentine following the dentinal tubular structure. The lesion spreads into an "anchor" or "fishing hook" shape when seen on histological sections. If left untreated, caries triggers enamel destruction and infection of the tooth pulp tissue. Caries is recognised as an infection. This new discovery opens the door to different techniques to control it, especially as we now see caries as a cyclical process fueled by a specific localized ecological niche of acid producing microorganisms when they are fed fermentable carbohydrates.

The early lesions described above are difficult to diagnose visually, as no or little evidence appears on the outer enamel surface except for pits and fissure stains; mechanically, as no macroscopic alteration in the enamel structure is present; radiographically (Christensen 1996) as a limited amount of minerals are lost, and radiographic evidence occurs only in later stages.

Whatever the pathogenesis of this new caries model is, new diagnostic techniques need to be found to detect and evaluate these lesions. Visual magnification, with the aid of dyes, laser induced fluorescence, and chemical reactions to bacterial metabolites are the main tools that can be used clinically. These diagnostic methods differ from the classical procedures because they do not look for

the loss of tissue, but aim at tracing the metabolic processes involved. Specificity and sensitivity of such methods allow a very early detection in metabolic changes (Anusavice 2000, Attrill 2001, Lussi 1993, Lussi et al 2001, Paterson et al 1991, Pinelli 2002).

Any further process, which involves irreversible tissue destruction, can only be described in terms of impairment, disability and handicap. Any later diagnosis is the naturalistic observation of the absence of self-regenerative resources, and possibly a failure on the clinician's part to correctly diagnose with modern diagnostic tools. At this stage, the only possible intervention is amputation of infected and necrotic tissues, and prosthetic replacement when possible and where available to reintegrate loss of function and ensure protection.

One of the benefits of early diagnosis is the rising of a new dental science, called minimally invasive dentistry, although the authors now feel that the new standard of care should be termed "*micro-invasive dentistry"*. It still performs amputations, but due to early detection, they are very small cavities. Procedures are quick, no or little pain is caused and no local anaesthesia required in the majority of cases. Fillings are very small and consequently longer lasting (Christensen 1999).

The ideal treatment has two objectives: arresting any microbial metabolism and boosting the natural host defense in a short period of time and with long lasting effects. Therefore, dental caries can be redefined as a reversible metabolic process.

Research has shown that fluoride only partially fulfils these requirements, and so do other disinfectants or antibiotics. Fluoride's effects take a long period of time to establish protection, and these effects may be more significant in the old caries model rather than the new model of caries. New data suggests that fluoride merely delays the onset of caries, as when the subject moves out of the family and home-care environment, oral hygiene becomes may become worse, and factors that allow demineralisation and infection may start to predominate.

Up to the present, it the wide belief was that dental caries is an infective process and the only real 'treatment' option was the cutting away, or 'amputation', of all diseased tissue and its replacement with some form of restorative material. This is the teaching that most dental students still receive at dental schools around the world today, and is practiced by the majority of dentists around the world.

This invasive process involves needles, injections and drills. It is a highly stressful treatment for everyone concerned. This amputation approach has not changed for over 100 years. What has improved in recent years is the general dental practitioner's understanding of the carious disease process. The prevention movement established in the 1970's attempted to educate people that the real treatment of the disease is centered on changing the diet and in improving plaque control combined with the use of fluoride containing products. It is known that people are highly resistant to accepting messages of good health education and effecting change through these messages. Some general dental practitioner do not put enough effort into presenting convincing dental health education to their patients, neither is the average dental practitioner well trained to do so. Sitting in a dental surgery, surrounded by the tools of drilling and filling, some patients fail to understand what the hard working dentist tells them! They may feel intimidated, uncomfortable and sceptical because they may not be well informed.

The best option to avoid such stress and discomfort is minimal invasive dentistry. Minimally invasive dentistry has advantages for the patient and general dental

practitioner. Many techniques however still involve the physical removal of tissue before the final restoration is put into place. The ideal treatment solution is the simple removal of the cause of the disease with no associated loss of sound tissue and no associated physical discomfort for the patient. This is now available with recent advances in the field of ozone treatment and the HealOzone delivery unit (Baysan et al 2000, Baysan 2002, Bayan & Lynch 2004, Baysan et al 2004, Baysan et al 2001, Baysan & Lynch 2001, Holmes 2003, Lynch 2003, Abu-Naba'a, 2003, Abu-Salem 2004, Domingo & Holmes 2004, Holmes 2004). For the first time, the general dental practitioner can break the vicious circle of restorative dentistry, as it would appear that it is no longer necessary to place the initial restoration that will require eventual replacement and subsequent re-treatment. By breaking this cycle, the patient enters into a treatment pattern that is less frightening, simpler, quicker and more efficient. For the general dental practitioner, this treatment technique is simple. It provides greater efficacy for the dental practice, it is profitable (Domingo & Holmes 2004), and the practice team will not have to cope with a waiting room full of anxious patients any longer.

Another advantage of the HealOzone treatment is that patients accept it willingly. In the past, continual advances in both materials science and treatment methods have brought outstanding benefits for our patients in terms of simplicity of the treatment. Successful dentine bonding systems have obviated the need for the design of the "Black" retentive cavity in most cases and hence dramatically reduced the use of the air turbine to design what may be termed as classical cavities. These bonding systems have allowed the general dental practitioner to concentrate almost exclusively on the removal of carious tissue while retaining as much sound hard tissue as possible. This was the first step towards the minimally invasive approach now advocated. However this carious tissue has still to be removed whether by use of the handpiece, air abrasion, or with hand instruments (ART) when used in conjunction with caries removing liquids and gels (e.g. Carisolv).

HealOzone treatment of dental caries removes the requirement for physical removal of infected tissue as remineralisation, not amputation, of carious dentine is promoted. The benefits to patients are therefore obvious. Most patients are scared and nervousness arises from their understanding that the hand piece may be an unpleasant and traumatic experience. Combined with the requirement for local anaesthesia, the fear has lead to the universally accepted misconception that the visit to the dentist is unpleasant. By using the HealOzone treatment, general dental practitioners are now capable of alleviating those concerns and improving the public's perception of dental treatments.

Nonetheless, there are still situations where treatment will follow more classical lines. General dental practitioners offer treatment of a wide variety without the need for local anaesthesia, drilling, and they are now able to treat many lesions in a short period of time. This procedure is entirely painless and atraumatic. Experience has shown that patients are delighted after treatment and are particularly motivated towards oral hygiene and dietary control when they realize that by improving and concentrating on these areas they can avoid the local anaesthesia/drill approach. .Patient acceptance is therefore virtually universal

The integration of the HealOzone treatment has altered the general practitioner's approach to the treatment of his or her patients in numerous ways and many thousands of Dentists in Europe have already treated tens of millions of their

Patients teeth using the HealOzone.: General dental practitioners have completely reassessed their diagnostic detection criteria of dental caries and treatment of the carious lesion. The dental probe is no longer of any use for fissure caries diagnosis. Consequently, examination should now be aided by the use of a digital intra oral camera combined with selective use of the DIAGNOdent.

This has several advantages to the examination appointment: It is simple and without trauma for patients. It also involves the patient in their examination. Dental surgeons see a dramatically increased awareness of oral health care for this reason. This in return helps explain the problems that may arise, and allows the patient to co-operate in the diagnosis and their treatment planning. From the clinicians point of view the advantages of intra oral imaging cannot be stressed enough. Images of the dentition can be magnified many times to assist in diagnosing. The enlarged direct vision of the region being examined on the monitor is an essential adjunct to the direct vision intra orally (Holmes 1995). This imaging combined with the use of the DIAGNOdent in areas where caries may be suspected results in an extremely thorough and meticulous examination and provides general dental practitioners with a quantitative assessment of any disease process present. Explaining to the patient what is required for treatment is very simple. Images can be shown on screen and the DIAGNOdent reading explained. This serves to additionally enhance the patients' confidence and education in oral hygiene and a healthy diet. Finally, these images can be stored with cross reference to the patients' notes for later use if necessary.

Following this examination, records are made of any positive DIAGNOdent readings and the particular teeth these are related to. This 'Caries Mapping' can then be used as part of a 'risk assessment', and to establish potential treatment needs. Treatment options can be explained to the patient and HealOzone treatment recommended where indicated. Images can be saved via the intra oral camera of the teeth to be treated, annotations made on the images about the lesion, appearance, etc and ozone is applied. There is rarely any requirement to make further appointments for the patient apart from the ozone review visits.

Hence the provision of ozone treatment is extremely time efficient, something which is valuable to clinician and patient alike. The patient's visit to the surgery is completely painless and atraumatic and they leave well informed and educated on both the reasons for treatment and what is required for a successful outcome. In addition to these factors, GDP's can look at the effects of the employment of HealOzone treatment on the dental profession as dentists. GDP's naturally subject themselves to a degree of stress as GDP's all desire to provide patients with pain free treatment as efficiently as possible. Using ozone treatment as the primary approach to the treatment of most dental caries removes most potential stressors. There is no local anaesthesia to give, usually no use of the drill or packing of restorative material. The time spent on providing the actual treatment is also minimal in the extreme. GDP's can therefore provide the most modern and most natural treatment available to their patients without fear that they may cause any physical or mental trauma – all the potential sources of stress for the surgeon in restorative treatment of the carious lesion are removed and yet GDP's are providing the very best in dental care.

Added Value.

Over the past few years the dental profession has enjoyed many technological advances in equipment and materials. Whilst the dental practitioner and his/her team may feel proud with their new 'toys', all too often the patients are not that impressed.

In all these practices where the ozone technologies have been brought into the clinical environment, the introduction of the ozone concept coupled with the DIAGNOdent has had a major impact with the patients and it has been quite remarkable. Treatment is no longer a stressful experience for either the dental team or the patient. In the case of children, their carers or parents do not feel anxious and there are no heart tugging screams as the needle is stuck through sensitive gums and soft tissue.
The ozone concept has had a significant impact on the dental team. The dental nurses and front of house staff have been very enthusiastic as they can see the effect the new treatment has on the patients. This adds to the positive atmosphere of the practice towards prevention and disease control. It does much to boost the morale of the team to witness nervous patients in much dental distress evolving into relaxed and appreciative individuals.

Costs of Traditional Restorative Care.

Filling materials fail at alarming rates. Costs can be measured in terms of pain, discomfort, and in financial terms such as lost productivity. In England and Wales, restorations carried out in National Health Service (NHS) dentistry cost a total of £1.25 billion in 2001. This does not include private treatment, which is currently estimated to be 50% of dentists' income. The total costs of all dental treatment in England and Wales probably exceeded £3.26 billion in 2001 (General Dental Council 2001).

Most of these fees are ascribable to fillings, root fillings, dentures, crowns and bridges. Published reports suggest 50% of restorative items are replacements for previous restorations, and about half of these restorations are being replaced due to secondary caries. If only 50% of all fillings could be avoided with the use of ozone, enormous sums of money could be saved. The cycle of filling preparation, reduction in tooth strength (Mondelli et al 1980) and subsequent replacement eventually may eventually lead to more complex restorative care requirements with increasing cost implications, such as the progression from a simple cavity, to a multi-surface one, to the fracture of the crown requiring root canal treatment, followed by restoration with a crown and core.

In the United States, dental treatment is estimated to cost $52 billion per year, and half of this cost may be associated with restorative treatment and the cost of missed workdays and lost production due to oral disease. Despite advances in clinical and laboratory research, approximately 50% of the U.S. population over the age of 65 shows evidence of root caries. In all countries, from the advanced to poor and developing countries, there is a huge potential for a cost-effective way to prevent and reverse caries. In the ageing population, and those with reduced manual dexterity, a preventative and early intervention strategy needs to be found. In this respect, the use of ozone should be also considered for medically compromised patients, domiciliary care patients and homebound elderly people. The equipment required is limited and essentially portable compared to that required for conventional drill & fill. Therefore elderly patients who have limited access to the dental services can benefit from this treatment. In some poor, developing and highly populated countries, equipment, dental supplies, and dental services are inadequate due to high costs and lack of dentally trained personnel, root caries is still a problem (Galan & Lynch 1993, Beighton et al 1993)

Even if ozone therapies could save just 50% of all the fillings placed, the cost savings are huge. The research shows us that over 90% of fillings could be saved. In

the modern world, where centralised welfare is being reduced to contain finances, the implications are enormous.

Conclusions

Domingo *et al* (Domingo et al 2004) compared ozone with conventional drilling and filling for the treatment of root caries. They found that ozone therapy was on average 40 times quicker than 'drill and fill' and 3.6 times less expensive.

Johnson *et al* (Johnson et al 2003) carried out a cost–benefit analysis of the treatment of occlusal or root caries using either ozone or conventional therapy (several steps including local analgesia, drilling and filling). They found that ozone therapy took significantly less time than conventional treatment and was also less costly. In this study, ozone therapy required a minimum of 3 minutes chair time compared with 20 minutes for conventional treatment.

Patient preference studies have shown that the avoidance of injections and drilling reduces treatment anxiety. In a number of studies, patients have even expressed a willingness to pay more for the HealOzone treatment.

The avoidance of conventional restorations has far reaching benefits. A conventionally restored tooth is at risk of future re-intervention either as a result of material failure, caries progression or tooth fracture. Re-interventions can include re-restoration, root treatment, crowns and extraction. If fewer teeth are drilled and restored, fewer teeth will require re-intervention and therefore fewer patients will require further injections and drilling. The patient is also more likely to keep their original dentition. To estimate the proportion of a patient's life to which this utility gain may be attributed is clearly very challenging.

HealOzone is a proven innovative technology that offers patients with dental caries the possibility of a safe, effective and predictable treatment reducing the need for injections, drilling and restoration. Furthermore, HealOzone offers the potential to maintain the original dentition and avoid the anxiety, discomfort and cost associated with invasive interventions such as root canal treatment and extraction.

Patients that have received treatment with the HealOzone have shown a preference for this therapy. HealOzone could be offered as an addition to current treatment options for dental caries in at least 80% of cases.

Whilst HealOzone leads to an incremental cost in the short-term, this novel treatment method offers the potential to improve long-term oral health and avoid the substantial costs associated with re-intervention in restored teeth. Soon after the introduction of this technology, the effect of cost savings from re-restorations avoided would be enormous. The longer term treatment with HealOzone leads to even greater substantial cost savings, particularly where the need for other re-interventions such as root treatment, crowns and tooth extraction are reduced.

In the previous pages, we have introduced the concept of alternative strategies for the treatment of decay, and discussed the ozone treatment of cavities. The 'drill and fill method' and ozone treatment were weighted against each other and the HealOzone unit available from KaVo was described with some of its advantages and ways of use. An explanation of the Heal Ozone's benefits for the patient and dental practitioner was provided as well.

This second part will focus on the ozone treatment of deciduous teeth lesions, treatment of permanent teeth lesions, treatment of primary pits and fissure carious lesions (PFCLs), treatment of root caries, treatment of the larger carious lesion and patient compliance.

The last part will focus on the use of the Healozone during tooth whitening, root canal therapy, and treatment of fractured cusp syndrome, fractured teeth, dentine hypersensitivity, post-operative pain, soft tissue lesions, treatment of dry sockets, and treatment of apthous ulceration, sterilisation, dental unit water lines and prevention of demineralisation surrounding orthodontic brackets.

Ozone therapy provides a treatment with benefits for dental patients of all ages. It is applicable to a wide range of conditions of the intra-oral hard and soft tissues. The treatment of carious lesions is effective and much more acceptable for the patient than the "drill and fill" method. This makes it especially attractive to younger patients, who are often scared of the "drilling". For the elderly people with medical problems, that can complicate conventional dental treatment, the ozone treatment is also easier and more efficient. The treatment is simple, completely safe and often eliminates the need to introduce potentially toxic restorative materials.

Patients are happy after the uncomplicated ozone treatment and their enthusiasm could create a 'buzz' in the local community. The more patients know about the ozone treatment, the more benefits it will bring to the community. Anything that can help slow down dental decay, treat caries and eliminate the fear of dentists is welcome nowadays. The HealOzone users' experiences have shown that the ozone concept enhances the general dentist's ability to talk to patients who rapidly understand the new method. It seems to stimulate their interest. The therapy has also proven be a financial asset within the dental practice.

The precision of treatment consists of the high oxidative action on substrates and microorganisms. The treatment is supported by the very rapid kinetics of ozone oxidative reactions, and by the long lasting effects of remineralisation.

Hundreds of clinical and laboratory studies on non invasive ozone treatment in oral and dental pathologies are either completed or are underway, filling the gap between the naturalistic observations and the comprehension of these complex mechanisms and pathways. The dental community is increasingly sharing the awareness that ozone indicates new preventive and therapeutic possibilities, which have never been achieved before and allows a new vision, which complies with needs and demands of the public for non-invasive and effective preventive dental care.

From a public health point of view, with dental caries being such a problem in large areas of the world and with such a shortage of clinicians in some parts of the UK and Europe, the ozone therapy has a major part to play in the prevention and treatment of dental caries. The HealOzone machine and the DIAGNOdent are portable and it is possible to envisage units being used with great effect in dental practices and

community clinics, as well as during domiciliary visits to Patients homes. It takes so little time to treat several teeth that it is possible to help many more patients compared to conventional treatment. Dental hygienists and therapists are ideally suited to providing the treatment for all categories of patients. Members of the "Dental Team" could be easily trained to provide treatment to large numbers of Patients in the developing world.

However, the dental profession may need to return to the basic concepts of a preventative approach. The diagnosis of caries is a failure in preventing it. Ozone certainly plays a major role in every preventative-orientated dental practice.

According to "The Niche Environment Theory", an "ecological niche" of microorganisms is established within a carious lesion. Microorganisms are far from the 'simple bugs' they are often referred to. They have survived for millions of years, whereas humans have a minute time frame of existence in comparison to the period of existence of microorganisms. Dental practitioners should not be surprised to find out that bacteria set up complex interactions with other microorganisms, communicate with neighboring colonies at times and call for help from others when their host attempts to change their environment. Protein coatings, plaque and debris are known to protect these colonies by acting as a protective coat, reducing the effects of pharmaceutical agents designed to eliminate these microbial colonies.

The concept of dental caries has changed in the last decade. Investigations disclosed the complex mechanism of effects of demineralisation and remineralisation that take place daily in oral hard tissues through interaction with saliva. The dental profession has recently acquired a completely new view of an old pathology. Decay starts as a metabolic imbalance, shifted towards acidity and demineralisation. This process develops in dental plaque. In this kind of environment acidophilic and acidogenic bacteria develop an 'ecological niche'. Consequently, new methods of diagnosis of caries need to be found (Pinelli et al 2002, Tam & McComb, Ricketts et al 1997, Schopbach et al 1995, Ekstrand et al 1998, Lynch 1996, Lynch & Beighton 1993, Beighton et al 1993).

Early in the development of a carious lesion, when enamel and dentine are demineralised and dentine has not been denatured by proteolysis, these dynamics can be easily reversed, and remineralisation can occur if the local environment is altered by reducing causative factors. When the microbial ecological niche is eliminated, remineralisation rapidly occurs as the previously cyclical demineralisation and remineralisation cycles are shifted towards a predominance of remineralisation.

The carious lesion progresses when conditions are suitable for acidogenic bacteria to release acids as metabolic by-products. The acids produced lead to a breakdown of mineralised tooth structure. At times, an equilibrium situation occurs when the rate of mineral gain equals the rate of mineral loss. Ozone does not only remove the protein protection layer and is bactericidal, through its powerful oxidizing properties, but it also oxidises biomolecules that allow the niche to survive and expand. This severely harms the microbial population in the carious lesion and obliterates the cariogenic microorganisms and the ecological niche. This brings the equilibrium to a level where re-mineralisation can predominate and occur. No more acid can be produced within the lesion when the acid-producing flora is eliminated. For example, the acid pyruvic acid, one of the strongest naturally occurring acids

within carious lesions, manufactured by bacteria, and involved in the development of caries, is oxidised by ozone to acetate and carbon dioxide (Lynch et al 2001, Silwood et al 2002, Silwood et al 2002). Acetate is much less acidic than pyruvic acid. The decarboxylation reaction leads to mineral uptake due to the more favourable Ph conditions in a carious lesion. As soon as ozone therapy takes place, and saliva enters the treated surface, the lesion will become populated with normal mouth commensals. These do not produce the acids associated with the progression of caries and immediately the carious process shifts to a predominance of remineralisation.

Evidenced based dentistry proving the efficacy of the HealOzone to reverse caries.

Ozone has shown to be safe (Baysan 2001) and clinically effective in the management of root carious lesions (Baysan et al 2002, Baysan & Lynch 2001, Baysan et al 2001, Baysan 2002, Holmes 2003) and many other types of carious lesions as will be discussed in this paper. There is extensive evidenced based dentistry clearly documenting the reversal of caries, clinically proven to significantly reverse at 4 weeks after treatment. The recommended treatment at the 4 weeks recall is to Ozone treat the lesion again. In the case of pit and fissure caries extending just into dentine, the pits and fissures are then sealed.

Twenty-two studies have been published reporting on the safety and effectiveness of treating root, pit and fissure caries with the HealOzone device. Three studies were published as full papers in refereed journals, while the remainder have been presented as abstracts or posters at conferences and published in the Journal of Dental Research. In addition, 5 studies have been presented as part of PhD and MPhil theses all of which were awarded without criticism and examined by world leading authorities in Cariology.

It is worth noting that the following accolades have been bestowed on three HealOzone researchers, which should send strong messages to the World's dental community.

- Aylin Baysan won First Prize at the 2001 International Association for Dental Research (IADR) meeting for her research methodology.

- Layla Abu-Naba'a won the prestigious "Basil Bibby" First Prize from the Cariology Group at the 2002 IADR Meeting related to her HealOzone research into the reversal of pit & fissure caries.

- Julian Holmes won First Prize at the 2004 IADR Meeting in Hawaii for his HealOzone research into the reversal of root caries at 21 months follow-up. His 24-month data has just been published

It is difficult to recall any other caries-related product or technique, which has received so much International acceptance and recognition at this highest level.

Sixteen of the above studies were randomised controlled trials and 2 were microbiological studies. In addition, 4 studies were included that made assessments of patient attitudes to dental treatment including ozone.

Details of the clinical studies are listed in the references.

The trial sizes ranged from 17 to 377 patients, with occlusal pit and fissure caries in both deciduous and permanent teeth, and root caries. Time between initial treatment and reassessment varied from 1 month to 24 months, and some trials reviewed patients more than once. The treatment time with ozone varied between studies from 10 seconds to 40 seconds. All patients received initial treatment with ozone, and in some circumstances patients were also re-treated at each review. Trial comparators were generally no treatment or placebo treatment with air being applied through the HealOzone device. 5 studies referred to current treatment options, including sealant and 'drilling and filling', of which 3 had patient centred outcomes as their primary study result.

The major outcomes of these trials include changes in caries severity and reduction in total caries associated micro-organisms.

The root caries lesions often occur with elderly patients who may have associated medical problems, which complicate their dental management. With the use of ozone therapy, such lesions are easily treated. The portability of the HealOzone unit facilitates its use in the domiciliary setting and treatment is simplified because the clinician does not need to carry a range of restorative materials on such visits. Dentists using the HealOzone unit for caries management encourage their patients to regularly use a fluoride and mineral containing mouthwash, which will enhance the efficacy of ozone by promoting re-mineralisation. Part of the oral hygiene message is that they should reduce the frequency of consumption of fermentable carbohydrates.

Using ozone treatment as the primary approach to the treatment of many forms of dental caries completely removes any potential stress factors. There is no local anaesthesia to administer, no use of the drill and no packing of restorative material. The time spent on providing the actual treatment is also minimal. All the potential sources of stress for the dentist in restorative treatment of the carious lesion are removed and yet these General dental practitioners (GDP's) are providing the very best in dental care. GDP's can therefore provide the most modern and most natural treatment available to patients without fear that they cause any physical or mental trauma.

All these factors also apply to the final restoration of the ozone treated tooth. Where the remineralised lesion is not visible, especially with root caries, it can be left without further intervention. Reasons to place a final restoration include:

- to prevent food packing and food trapping which may lead to caries in adjacent teeth, or localized periodontal disease (if approximal).
- cosmetic reasons (remineralised carious tooth tissue may sometimes darken considerably). This can obviously lead to cosmetic concerns, especially in the anterior labial surfaces of the anterior teeth region and hence placement of a restorative material may be required purely for aesthetic reasons.

Treatment of deciduous teeth lesions:

The provision of dental treatment for young people can have long lasting effects. If dental care is painful and unpleasant, as these patients grow into adults, they will tend to only attend when if pain. As all dentists know, at this stage restorative care tends to be more difficult, more extensive and has increased cost implications. The use of ozone (Abu-Salem 2004) and mineral releasing glass ionomers can play a significant role in the dental management of these patients. As confidence in the treatment by the patient and parents or guardians is gained, so the compliance with important oral hygiene messages will be increased (Domingo et at, 2002, Domingo et al 2003).

Treatment of early pit and fissure carious deciduous teeth lesions

The management of early pit and fissure carious lesions has been extensively studied by Abu-Salem (Abu-Salem 2004). Non-cavitated occlusal carious lesions were used in this study. Teeth were cleaned using an air-abrasive system, then the following were recorded: clinical severity index, DIAGNOdent and ECM IV readings. After randomisation, one lesion was ozone treated and another was reserved as a control in each child. No adverse effects were recorded. Ozone treatment significantly remineralised lesions ($p<0.01$) whilst lesions in the control group suffered from deterioration in their mineral content. Therefore, ozone treatment was as an alternative treatment for non-cavitated occlusal carious lesions in primary teeth

Treatment of deciduous teeth lesions, visible radiographically:

Where caries is found where the radiolucency is visible radiographically, but not exposing the pulp, this can extend more than half way into dentine. It is relatively simple to treat using a modified atraumatic restorative technique (ART) combined with Ozone. The application of, for example, FujiVII (GC Japan) may supply long-term fluorine and mineral release, as well as preventing ingress of food debris and re-establishment of the acid-niche environment. Treatment is simple, fast (the average ozone application time for practitioners using the HealOzone is 30 seconds) and involves little preparatory work. The loose debris and outer necrotic carious dentine layer is first cleaned away, until a leathery base is reached. This can be done with hand instruments. Ozone is applied, the lesion wetted with the HealOzone (KaVo) remineralising wash and then the glass ionomer restorative cement can be applied. This modified ART technique, combined with Ozone, has been clinically proven by Holmes (Holmes 2004).

Occasional stabilisation of deciduous teeth lesions with a hopeless prognosis:

Allied to this ozone has been used in the treatment on deciduous molar teeth with hopeless prognoses as a result of caries. In some parts of the UK and USA it is upsetting to find so many children at 3 and 4 years of age with gross decay. For these patients the usual outcome is a general anaesthetic and teeth extraction. These lesions are treated with ozone and Dentists have found that the majority of children are co-operative and actually enjoy the experience (Holmes 2004). What has been found of great interest is that the toothache in young children has been reduced and even abolished after ozone treatment, with much relief for the parents (Holmes 2004).

Ozone treatment seems to be an excellent palliative treatment option for such youngsters.

Treatment of approximal deciduous caries where the adjacent two marginal ridges are intact.

When treatment is required for these lesions then an operative approach gaining access to the caries is used combined with Ozone, in a similar way to that described above managing deciduous teeth lesions, visible radiographically

Prophylactic treatment of erupting molars in high caries risk children

Ozone is used instead of fissure sealants during the eruption of the permanent dentition and prophylactically in populations at risk of developing carious lesions. It is possible that some fissure sealant techniques needs to be re-examined. Current protocols for fissure sealants include the use of a bristle brush and pumice to clean the occlusal surfaces of teeth prior to sealing

Treatment of permanent teeth lesions:

Can we simply seal in infected caries?

Sealing in caries has been clinically proven to not be successful as is evident in the studies published by Weerheijm et al. (Weerheijm et al 1992) as well as Poorterman et at (Poorterman et al 2003). In addition, it is possible that food debris and microorganisms will also remain impacted at the depths of the fissures as the bristles are not small enough to clear out the impacted debris. Micro-leakage might also allow the acid-niche to resume its activity, and over a period of time, the surface might collapse into a large carious cavity. It is also possible that the cariogenic microorganisms within the lesion can be capable of receiving nutrients via the pulpal fluids.

Weerheijm et al. (Weerheijm et al 1992) published an excellent study, which was a retrospective examination of sealed teeth where radiographs showed radiolucencies in dentine beneath sealants that were clinically intact. Cariogenic microorganisms were found in 50% of the teeth and the dentine was often soft and moist, rather than leathery or dry. This would indicate active lesions under these "sealed" restorations. The microbiological tests in this work were more detailed than in many other studies examining for lactobacilli, mutans streptococci and non-mutans streptococci.

Poorterman et al (Poorterman et al 2003) analysed the status of 705 occlusal surfaces of first and second molars of 90 17-year-olds longitudinally in a 6-year follow-up, using a combination of clinical and radiographic information. Clinical data were used from an epidemiological project. Between the ages of 17 and 23 years, about one third of sound occlusal surfaces developed new dentinal radiolucencies, and over 70% of existing radiolucencies showed progression, both irrespective of the

presence of a sealant. In both examination years, almost 20% of the restored surfaces showed signs of a dentinal radiolucency. It was concluded that at the age of 17 occlusal surfaces are still highly susceptible to new dentinal carious lesions and further progression of dentinal radiolucencies already present.

Rationale for Ozone treatment prior to fissure sealing.

It is known that it can be difficult to detect caries within pits and fissures. These above mentioned studies by Weerheijm et al and Poorterman et al would provide a logical reason for using Ozone prior to the application of fissure sealant restorations.

Rationale for using air abrasion with Ozone and sealants.

Preparation systems, such as the KaVo PROPHYflex or similar, or air abrasion such as the KaVo RONDOflex or Danville PrepStart can be used to assist the detection of caries in teeth deemed to require preventive resin restorations. As mentioned earlier, the bristles used to manufacture the bristle brushes are often larger than the fissures being cleaned. However, air abrasion powders (average particle size 27 microns) will flush out the debris, prepare the fissure for acid etching, and produce a more reliable sealing along the fissure edges, as well as removing all the debris within fissure patterns, thereby allowing Ozone to penetrate more easily into the fissure patterns, prior to sealing. .

Treatment of primary pit and fissure carious lesions (PFCLs):

PFCLs can manifest in different forms. Early diagnosis of primary pit and fissure caries is of great importance in children and adults. The carious lesion is difficult to diagnose with the traditional methods, such as intra-oral radiographs, the mirror, and the outdated "probe technique". The low diagnostic sensitivity of visual, probing and bitewing examination leads to a significant number of teeth with dentinal caries being undetected beneath apparently "clinically intact" pits and fissures. Lesions have a natural history of deepening into dentine leaving a macroscopically almost undamaged enamel surface, the so-called 'Hidden Lesion', or 'Hidden Decay'. Radiographs do not show the evidence of decay unless the lesion is more than 3 mms deep. The absence of macroscopic cavitation prevents hardness measurements in dentine. Systems using indirect light fluorescence have been demonstrated to be effective in the clinical diagnosis of decay in the permanent and in the deciduous dentition.

Ozone treatment of early occlusal carious lesions with carious dentine extending up to 2mm in depth.

These lesions will not be visible on bitewing radiographs and have been proven in numerous clinical trials to be easily reversed within 4 weeks after Ozone treatment for 40 seconds. The sequence of care, which needs to be provided is as follows.

Ozone-treat all these early occlusal carious lesions with carious dentine extending up to 2mm in depth at the first visit

Advise the Patient to reduce the frequency of consumption of fermentable carbohydrate and to increase their use of fluoride containing oral health care products daily.

Recall the Patient in 4 weeks, retreat all the lesions with Ozone for 40 seconds and then seal each of these pits and fissures using either a glass ionomer cement or a flowable composite resin.

Ozone treatment of non-grossly cavitated occlusal carious lesions with carious dentine extending more than 2mm in depth.

These carious lesions are visible on bitewing radiographs.
The treatment for carious pits and fissures where there is infected dentine extending with a radiolucency visible on a radiograph requires some operative intervention. Following minimally invasive dentistry where approximately 1mm of the carious dentine is left on the floor of the cavity, ozone is then applied for 30 seconds. Restorative care is performed with a bonded composite resin after the placement of a glass ionomer cement base. Restoring either using a glass ionomer cement or using 15 seconds of phosphoric acid etching for enamel and a maximum of 10 seconds etch for dentine followed with a dentine bonding agent and finally composite resin, are again atraumatic and simple procedures for the patient and dentist alike.

Ozone treatment of grossly cavitated "deep" carious lesions

The treatment of the larger carious lesion comprises removing the outer necrotic decay, leaving 1mm of infected dentine overlying the pulp, ozone treatment and replacing the missing tooth structure by a restorative material. The larger lesions need special care. It must be stressed that larger lesions are not those to be treated with ozone alone; most will require a combined approach of traditional therapy, as well as ozone. As before, the aim is to allow natural remineralisation to take place on a predictable basis, without the wholesale destruction of tooth tissue. Where the lesion extends deep into the dentine, the basic protocol is the same; the soft outer necrotic caries is removed along with any unsupported enamel. Caries is removed to the leathery layer where it is judged that approximately 1mm of infected dentine remains. Ozone is then applied for 40 seconds or longer.. Then, the remineralising wash is applied.

Practitioners who use ozone in the large cavitated deep carious lesions (after the modified ART technique), are usually placing a restorative material such as FujiVII (GC Japan) or a composite resin to prevent food packing and food trapping which may lead to caries in adjacent teeth, or localised periodontal disease (if approximal).

In situations where severe breakdown of tooth structure has occurred, ozone may be used initially, combined with a modified ART technique, and either stabilised with a glass ionomer cement, or left "open" (as long as it is judged that the Patient will be capable of cleaning this lesion of all superficial plaque twice daily), to promote re-mineralisation, and when this has occurred, the cavity may be restored with a suitable restorative material.

Modified ART technique combined with Ozone

This modified ART technique combined with Ozone has been clinically proven by Holmes and Lynch (Holmes & Lynch 2004).The objectives of this study were to assess the hardness of ozone-treated dentinal caries 3 months after sealing and to compare the incidence of sensitivity associated with this technique with a conventional restoration technique. Subjects were recruited in a general dental practice, each with two non-cavitated occlusal carious lesions with radiographic radiolucencies extending 2-4mm into dentine. In each Subject, lesions were randomly assigned to either; Group 1; where air abrasion (PrepStart, Danville engineering, USA) was used to remove the unsupported enamel over the lesion and remove soft dentinal caries until the hardness was scored as leathery after probing. Approximately 1 mm of leathery caries at the advancing front of lesions was not removed. Ozone was then delivered for 40 seconds, a mineral wash (HealOzone, KaVo) applied and each lesion was sealed with a mineral-releasing glass ionomer.(FujiVII, GC Japan). For research purposes, after 3 months, the glass ionomer was carefully dissected and the floor of the cavity again probed, and then restored with a posterior composite; or Group 2; to drill and fill conventionally using a posterior composite. Each subjects daily used a re-mineralising toothpaste, spray and rinse (HealOzone, KaVo). Subjects were telephoned one week after each treatment and questioned about related symptoms and also recalled at 6 months. 16% of subjects receiving the posterior composite restoration at baseline complained of some post-operative sensitivity whilst no sensitivity was reported associated with any of the Ozone treated teeth ($P<0.05$). At 3 months all Ozone-treated dentine caries was hard and required no additional removal. This treatment using air abrasion, Ozone and sealing was associated with reversal of caries, more conservation of tooth structure and less sensitivity pain than conventional drilling and filling.

Leave the cavity "open" or seal the cavity after Ozone treatment?

There are two options of choice at this stage of treatment that HealOzone practitioners are using;

a. The lesion is left as self cleaning, and the patient is instructed with modified oral hygiene instructions. Patients are instructed to not eat any refined carbohydrates between meals and to dramatically increase their exposure to fluoride containing oral hygiene products. After routine brushing and rinsing, the patients are asked to place a small amount of the paste directly into the cavity. Then they spray two puffs of the remineralising solution directly into their mouths. This is repeated at least three times a day in addition to their regular cleaning techniques. During this brushing routine, these patients are also topping up their oral bio-available mineral concentrations by an additional two puffs, one in the morning, and another in the afternoon. This concerted loading of the patient's saliva mineral content has lead to reports from these practitioners of complete hardening and reversal of the carious lesions within on average 6 weeks when the HealOzone toothpaste, mouthrinse and spray are used as supplied from KaVo. This technique has been clinically proven to be particularly suitable to use for managing root caries.

b. The lesion is restored using a mineral-releasing glass ionomer, such as FujiVII or a resin-bonded composite. This will allow remineralisation to occur, without the possibility of ingress of food debris and re-colonisation of the cavity. Where this has been carried out, for example in the Class II type lesions extending into the approximal contact areas, practitioners are reporting complete remineralisation at 3-4 months on average. Remineralisation should occur from both the material, as well as the pulpal tissues. This technique has been clinically proven to be particularly favourable with managing crown caries, or crown-margin caries.

Have realistic expectations

It must be stressed that it is vital to control both the dentists own, and their patient's expectations. If the pulpal tissue is already necrotic, no amount of ozone will bring it back to life. Either root canal therapy or tooth removal is the only two viable options at this stage. However, the good news at this point, is that ozone can be used both in the root treatment cases, and to manage potential post-extraction pain by eliminating opportunistic infections in the socket and exposed soft tissue before healing has taken place (Holmes 2004). Ozone may also hasten the healing potential, and reduce the time taken to heal.

Antimicrobial efficacy of Ozone to kill cariogenic microorganisms.

Ozone is well known to be a powerful anti-microbial agent. Studies from Baysan, Whiley and Lynch (Baysan et al 2000) have demonstrated the anti-microbial effects of ozone in the treatment of root caries. . One study assessed levels of total microorganisms from a lesion biopsy taken before and after treatment with HealOzone. The other examined caries from freshly extracted teeth, removing and treating one half with ozone and the other with placebo, prior to assessing microorganism levels.

These studies showed a statistically significant ($p<0.001$) reduction in total microorganisms with ozone treatment of 10 or 20 seconds, compared to controls. The total microorganisms levels were less than 1% in ozone treated caries compared with controls.

Bacterial species of mutans streptococci are associated with caries development, with *S.mutans* and *S.sobrinus* being particularly associated with caries. Saliva coated glass beads have been inoculated with bacterial species *S.mutans* or *S.sobrinus*. Half were treated with 10 seconds of ozone gas and there was a significant ($p<0.0001$) reduction in both of these bacterial species compared to non-ozone treated controls

Reversal of root caries clinically using Ozone

All studies reported that root caries treated with between 10 and 40 seconds ozone either stabilised or reversed, while none of the ozone treated root caries progressed (i.e. worsened). Ozone is effective on caries of varying severity, including the severest soft caries, but these soft lesions should be treated with the modified ART technique

as described earlier. In comparison control caries did not change significantly or they worsened (Baysan 2002, Holmes 2003).

Caries reversal was observed in studies whether caries received a single ozone treatment or more than one over several months. The study of Holmes (Holmes 2003) showed that 3 months after a single ozone treatment of 40 seconds, 69% of caries had reversed to hard. Further re-treatment at 3, 6, 12 and 18 months, resulted in 100% of caries reversing to hard by the 18 month and 21 month reviews. It is difficult to hypothesise whether all the root caries would have reversed to hard without re-treatment, although Baysan *et al* (Baysan et al 2000) showed that 81% of caries had reversed to hard 3 months after a single 20-second ozone treatment. New data from the Holmes study (Holmes 2003, Holmes 2004) shows that at the 24-month follow-up, 100% of the ozone treated lesion arrested and reversed. However in the control group, only 2 arrested and reversed, despite the professional oral hygiene, increased use of remineralising products and improved oral hygiene.

The study of Baysan et al (Baysan et al 2000) further suggests that ozone treatment for 20 seconds was more efficacious than 10 seconds in reversing caries. Seventy three percent of caries treated with 10 seconds of ozone reversed. In comparison 100% of caries showed some degree of reversal when treated for 20 seconds.

The 12 month study of Baysan (Baysan 2002) showed improvements in both DIAGNOdent and Electronic Caries Monitor (ECM) readings for ozone treated caries compared to the control group after 1, 3, 6, 9 and 12 months. Both techniques are employed as diagnostic tools, correlating with the clinical severity indices employed by dentists and providing information on changes in tooth substance, porosity and mineralisation. In Baysan's (Baysan 2002) study, reduced DIAGNOdent and increased ECM values are indicative of a reduction in caries severity and tooth remineralisation. It should be noted that during the remineralisation process, some lesions may take up darker stains, leading to a stable or increased DIAGNOdent reading in a few cases. Such "false positives" need to be investigated and tested further, using a range of other diagnostic criteria, well known to dental practitioners, but this reinforces the need to use the DIAGNOdent to enter lesions but not to monitor remineralisation.

In addition, Baysan (Baysan 2002) has also published that DIAGNOdent and ECM readings suggest that treatment of root caries with ozone and root sealant is more beneficial than sealant alone, in terms of improvement in caries severity

If there are cosmetic concerns, such as remineralising stain root caries that are dark and unsightly especially in the anterior region, placement of minimal restorations may be required purely for appearance. For carious lesions ozone treated and left "open", any regions of remineralisation that have darkened during the course of treatment can be simply and effectively masked. The authors have found in many cases that previously active root carious lesions are easily masked using one of the more dentine shaded flowable composite materials or glass ionomer cements. These are extremely simple and rewarding materials to use and if placed correctly usually require no polishing, simplifying the treatment process even more.

Absence of any adverse events and side effects

Not a single adverse events or side effects have ever been reported during or after HealOzone treatment. In addition, detectable levels of ozone within the patients' mouths during treatment, with HealOzone, are below those recommended by the EU and FDA in ambient air, reflecting the lack of any danger of a Patient breathing in Ozone. At the present time of writing, there is not another delivery system that can boast this impressive safety record.

Patient centred outcomes

Studies have identified that assessed patients attitudes towards treatment of caries with ozone, compared with conventional drilling and filling. A total of 727 patients who were receiving ozone treatment for a carious lesion completed a questionnaire. They had all undergone conventional drilling and filling for a similar lesion either 3, or 6 months previously. In the study by Megighian & Dal Vera (Megighian & Dal Vera 2003) a further 45 patients were assessed who had undergone conventional minimally invasive treatment (drilling and/or air abrasion and drilling) in the past but had not received ozone treatment.

It is well recognised that some patients attending dental clinics show a level of anxiety which may cause some patients to not attend their clinic. In these HealOzone studies, 65%-83% of patients were anxious about their teeth being drilled and 80% were nervous about local anaesthesia. In comparison, 33% of patients were slightly anxious about ozone treatment based on a previous verbal description of the treatment. Remarkably, after receiving ozone treatment 80%-100% reported either a reduction or absence of anxiety about the treatment.

The majority of patients reported they were satisfied with HealOzone treatment (99%-100%). They were happy with the time the treatment took (97%-100%) and would like to use it again (100%) or recommend it to family and friends (95%-100%). Between 55% and 95% of patients would be satisfied to have the ozone treatment again even if it cost more than current treatment of drilling and filling. This result mirrors the studies of Domingo et al (Domingo et al 2003, 2003, and 2004)

Treating anxious children is a major challenge in dentistry, where treatment options may have to include use of sedation or general anaesthesia. The study of Dahnhardt & Lussi (Dahnhardt & Lussi 2003) evaluated parent's attitudes towards dental treatment in 20 very anxious children. Seventy five percent of these children were afraid of visiting the dentist prior to ozone treatment but following ozone treatment they lost some of their fear and all were happy to return for the follow up appointment. The majority of parents would use ozone treatment again (75%) and were willing to pay more for ozone treatment than conventional treatment using drilling and filling (80%).

Patient Compliance:

The majority of HealOzone practitioners noted that patients tend to respond enthusiastically to the concept of ozone therapy and the DIAGNOdent has proved to be surprisingly popular by patients of all ages. Patients are also keen to become involved in the DIAGNOdent readings. The audible signal produced by the

instrument when it encounters a suspect area has proved to be a revelation in itself. It is remarkable how the patient responds to this signal and child and adult alike remember their DIAGNOdent reading! Children even remember the colour of the soft rubber cup that was used and often chirp, "You used the blue one last time!"

It has been noted the much-improved oral hygiene in the patients treated with the HealOzone. The patients seem to 'switch on' to the concept and appear to be much more receptive to oral hygiene advice and are keen to participate in the use of the HealOzone toothpaste, mouth rinse and spray. The general experience in these practices has seen previously nervous individuals who normally do not like sitting in the dental chair, literally hopping in the chair to have ozone therapy. More smiles, more laughter, more enthusiasm all round.

In some Pathfinder Practices, other related research has shown that the patients all scored the highest marks for the procedure being comfortable and they all confirmed the experience was a positive one. Nervous patients stressed how they appreciated the treatment and that it gave them confidence about visiting the dentist. Everyone questioned said they felt motivated to modify their frequency of refined carbohydrate intake and to improve their oral hygiene as a result of the ozone experience.

This is an interesting finding as when questioned further, as the patients felt a degree of inevitability when faced with conventional fillings, even tending towards 'why should I bother' in terms of improving their diet and plaque control because 'I'll have to have a filling anyway'. Yet when they received the ozone therapy they reported feeling more optimistic and positive about changing their habits. Certainly, it is the general experience that the use of the DIAGNOdent and ozone, coupled with preventive advice does have a powerful impact on patients.

Interestingly when these groups of patients are offered the ozone pathway, the HealOzone practitioners have discovered a major change in their attitude toward oral health and these patients become excellent at keeping their appointments.

In conclusion, KaVo have received feedback from a large number of the 1500 dental practices who have purchased the Healozone up to 36 months ago. Many of these Dentists have described the HealOzone as an addition to their practice which they simply could now not live without. They describe the HealOzone as a win-win situation for their practice as well as for the Patients. Numerous dentists report earning the entire cost of the HealOzone within 2 months of use within their practice whilst ozone treatment is much less costly for Patients than traditional drill and fill techniques as well as being faster, painless, eliminates the cause of the problems and allows nature to remineralise their carious lesions via the patients own saliva. There is an observed change in the general public's demand for a homeopathic-type healing system, as an alternative to metallic fillings. Ozone treatment offers this choice of treatment modalities, provided the case is suitable, and provided the dental practitioner is aware of this new technology.

Further research

The continued commitment to research into the use of HealOzone in dentistry is essential and numerous on going studies are due for completion and publication over the next 12 months

Conclusions

The studies identified clearly demonstrate the safety and effectiveness of HealOzone in treating dental caries.

The treatment with ozone using the HealOzone device was shown to have a significant anti-microbial effect, destroying at least 99% of micro-organisms found in root caries, with 20 seconds of treatment. It is well recognised that the interaction of micro-organisms with plaque and the tooth structure are essential for the inititiation and progression of dental caries.

Detailed comparison between trials is usually problematic given the difference in treatment duration, treatment frequency, follow up time and initial severity of caries. However, the common outcome for ALL the studies is clear. HealOzone was shown to have a stabilising or reversing effect in both root and pit and fissure caries of varying severity in permanent teeth. The repeat ozone treatment and sealing of pits and fissures, where the caries had spread less than 2mm into dentine, has also proven be an excellent technique, and much more cost effective than the alternative of injections, drilling and filling. The reversal of non-cavitated pit and fissure caries in deciduous teeth is also proven. The reversal process is associated with remineralisation of the tooth and this was demonstrated using clinical techniques to quantify this, as well as ECM and DIAGNOdent measurements in many of the studies.

The use of HealOzone therefore not only preserves tooth structure by avoiding the use of invasive techniques removing decaying tissue, but also destroys the micro-organisms responsible for the decay and promotes caries reversal and tooth remineralisation. This process occurs naturally from the saliva which is saturated with calcium and phosphate.

Patients treated with HealOzone revealed that they were extremely well satisfied with the treatment. The significant levels of patient anxiety associated with 'drilling and filling' techniques were significantly reduced when patients underwent the ozone-based treatment.

Tooth whitening:

Teeth may be whitened using ozone, due its strong oxidising properties. The situation that is often encountered is the discoloured incisor that has been previously root-filled. This condition is readily treated with hydrogen peroxide and sodium perborate mixture or car amide peroxide gel and is practiced as the 'Walking Bleach' method. The application of ozone to the mixture will greatly enhance the whitening effect. The chosen whitening agent can be applied to the access cavity in the usual way and ozone applied from the HealOzone unit. The ozone gas then dissolves in the hydrogen peroxide mixture and these oxidants synergistically bleach the tooth. The cavity is sealed with an acid-etched composite to retain the mix inside the cavity, and

the tooth left for a week for the whitening to occur. Studies are currently under way using ozone as a means of bleaching vital teeth where again the Ozone is applied directly on to the concentrated hydrogen peroxide placed on the surface of the tooth.
In Cuba, published work shows that non-vital tooth whitening can be achieved with ozonated oils.

Root Canal Therapy:

The aim of conventional root canal therapy is to provide a clean, shaped, root canal that facilitates the placement of an adequate root filling. There may be multiple canals, frequently linked by a "web" of accessory canals. There is the so-called "apical delta" and the common lateral canals. Until recently, the dental profession relied on irrigants to try to reach these areas to disinfect and dissolve organic debris where it is impossible to instrument mechanically.
In this situation, current procedures can again be modified, as with whitening, to greatly improve the quality of treatment for patients. When irrigating with the usual irrigant solution, for example sodium hypochlorite, ozone can be applied into the hypochlorite solution in the root canals. This technique allows the root canal system to be thoroughly disinfected and possibly be sterilised. In cases where previous root canal treatment has failed, Enterococcus faecalis seems particularly prominent and especially difficult to eradicate. Ozone will eliminate this bacterial type (Chang et al 2003). It is also postulated that ozone might penetrate through the apical foramen, and enter into the surrounding and supportive bone tissue. The effect of ozone on these tissues or indeed on pulpal tissue might encourage healing and regeneration (Bocci 1996). Cytokines are proteins, which are released from cells in an inflammatory process that activate, mediate or potentiate actions of other cells or tissues (Bocci 1999, Bocci 2004, Fouad et al 2002, Trowbridge 2003). Many cytokines are released after exposure of blood to ozone and these include tumor necrosis factor-α, interleukin-2, interleukin-6, and interleukin-8 .
The dental pulp is a dynamic tissue, which is exceptionally sensitive to its oral environment even though protected by dentine and enamel. Upon an insult such as mechanical trauma to the tooth crown, or microbial invasion, the inflammatory response is elicited, with elevated levels of cytokines such as interferon-γ, interleukin-4, interleukin-10, and interleukin-12. Interleukin-6 in a symptomatic pulp can be increased by 3000-fold , while levels of interleukin-2 remain unchanged (Anderson et al, 2002, Hunag 1999,)

To date, numerous abstracts have been published demonstrating the reversal of caries of enamel and dentine through the use of ozone, but no study has yet discussed the possible effect of ozone on the pulp. Thus, this research project aims to investigate, the possible inflammatory response that may be induced in the pulp by exposure of the tooth crown to ozone.

Hundreds of practitioners from the HealOzone pathfinder group have treated such cases with excellent results.

Treatment of fractured cusp syndrome:

The symptoms of sensitivity and pain on release of pressure related to the fracture of a cusp can again be successfully treated with HealOzone. The exact

location of the fracture is helpful in our approach to ozone treatment and can be ascertained through careful examination and the use of intra oral imaging. Once the fractured area is diagnosed, a seal is obtained covering the cusp and fracture line in question and application of 40 to 60 seconds of ozone followed by a remineralising solution wash often leads to elimination of symptoms. This obviously cannot cure the underlying problem of tooth fracture however, the removal of acute symptoms by such a simple means is most beneficial for the clinician and patient alike. Numerous practitioners from the HealOzone pathfinder group have treated such cases successfully.

Fractured teeth:

Posterior teeth with fractures along the pulpal floor, often present with symptoms associated with reversible pulpitis. This is thought to be due to bacteria tracking along the line of the fracture and resulting in inflammatory pulpitis. Such lesions have been traditionally difficult to treat, but if the restoration is removed, the fracture site determined and ozone applied, resolution of the pulpitis may be obtained as the bacterial load is reduced within the fracture line. The base of the cavity may then be sealed with a dentine bonding agent or glass ionomer cement prior to restoration with a suitable restorative material.

Where patients attend with fractured anterior teeth, conventional teaching tells the dental practitioner that after time, the pulpal tissue is infected, and will die. Numerous practitioners from the HealOzone pathfinder group have treated such cases up to 48 hours after injury. Local anaesthetics should be used prior to treatment. In these cases, 2 minutes of ozone seems to be the average applied. From the work of Professor V Bocci (Bocci 1999) in Italy, it is known that ozone not only sterilises the tissue, but also induces the reparative and regenerative mechanisms. Once the exposed pulpal tissue and surrounding tooth structure has been sealed (it has been shown by John Kanka III, USA that acid etch and resins will not kill nerve tissue) the tooth can be reconstructed. Many pathfinder dentists have maintained vital teeth up to 36 months for their patients treated in this way.

Dentine Hypersensitivity:

Exposure of the dentinal tubules with related symptoms of sensitivity is an extremely common problem presenting to the general dental practitioner. All treatment methods are directed at the sealing of these tubules and vary from the application of fluoride varnishes to the placement of bonding systems on the root surface. The "hydrodynamic theory" proposed to explain dentine hypersensitivity has been around for some time. As well as fluid movements within the dentinal tubules, bacteria have also been shown to be associated with the tubules. This problem can be simply and immediately eliminated with the use of HealOzone treatment. Ozone penetrates exposed tubules, eliminating bacterial contamination and effectively "priming" tubules to allow mineral ingress and subsequent sealing. It is vital that the seal obtained allows ozone delivery to the area being treated and in these cases, the use of liquid rubber dam is a great aid to achieving this seal around the marginal gingivae. Once a seal is obtained, an ozone delivery of 40 seconds is followed by painting the treated area with the supplied CurOzone remineralising solutions. This protocol is usually sufficient to completely eliminate any symptoms from the area undergoing treatment. In more severe cases, a second 40-second application of ozone

may be required. A final application of fluoride varnish may be performed and the patient is given oral hygiene instruction and advice about erosion before leaving in order that future problems of this nature can be prevented. Over the last 3 years, hundreds of the pathfinder group of dentists have reported excellent results using this HealOzone technique. It seems that ozone not only allows deep dentinal tubular remineralisation, but also may stimulates the pulpal tissue to switch off the pain signals. Results of this technique were published by Holmes & Daly (Holmes & Daly 2002) in the journal Dental Practice.

Post-operative Pain:

This is commonly reported, following cavity or crown preparations. Traditionally this has been explained as being due to thermal trauma to the pulpal tissues. Current thinking suggests that, associated with the pulpal trauma, there may sometimes also be some bacterial ingress into the dentinal tubules. This bacterial contamination of dentine may lead to an inflammatory reaction within the pulp. The patient with the resulting pulpitis will complain of hypersensitivity to thermal changes, and pain. The pulpitis may become irreversible and this may necessitate endodontic procedures to relieve the symptoms.

If ozone is applied to the cavity and crown preparations when completed and prior to restoration placement, the degree to which the dentine becomes infected with bacteria is reduced. This reduction in bacterial count may reduce the symptoms of post-operative pain and thus reduce the need for endodontic procedures in such situations. In addition, this technique is also useful to eliminate any microorganisms that might be inadvertently left behind in some missed caries. Studies shows infected caries is commonly left behind after cavity preparation by dentists.

Soft Tissue Lesions:

There is anecdotal evidence to support the use of ozone therapy for soft tissues lesions, such as apthous ulcers, "cold sores", and dry sockets. The mode of action is thought to be due to a reduction in the bacterial population associated with such lesions, due to the bactericidal effects of ozone. This use of ozone is also supported from the many studies in general medicine where ozone has been used in 'bagging' techniques.

Treatment of dry sockets:

Post-operative infection following extraction is unfortunately a common complication. Again, as ozone is totally bactericidal, in theory GDP's should be able to treat such problems very simply. Practitioners have had great success using ozone for this application. Once a seal is obtained around the infected area, a delivery of 60 seconds ozone has lead, in all cases treated to date to complete resolution of symptoms within 48 hours (Holmes 2004). Ozone seems totally effective in the management of dry sockets and prevents the requirement for systemic antibiotic treatment.

Treatment of apthous ulceration:

The symptoms of major apthous ulceration can be severe and extremely distressing for dental patients. Current modalities of treatment are primarily aimed at symptomatic relief, as generally the aetiology of apthous ulceration is idiopathic. It is simple to form a seal over the ulcer using a large cup and deliver 40 seconds of ozone to the lesion. In all cases, the symptoms dramatically decreased within 24 hours and in 3 cases completely resolved within 48 hours (Holmes 2004). Again, this is a very relevant application as apthous ulceration can be a very severe problem for some patients and in the absence of causative factor ozone treatment may be extremely useful to aid in the resolution of the symptoms our patient's experience.

Dental unit water lines:

These have been shown to be heavily contaminated with biofilm and high bacterial counts have been recorded in the water from dental units. This does not seem to have any serious effects in the general dental practice setting but may be more worrying where immuno-compromised patients are concerned. Biofilm contamination plays havoc with dental units, often causing annoying blockages in couplings, hand pieces and 3:1 syringes.

Initial research on the use of the HealOzone, applied to water lines via the dental unit water supply, has shown greatly reduced numbers of bacteria present and also a significant reduction in the biofilm present (Abu-Naba'A et al 2003). It is interesting to note that the HealOzone unit may be adapted to allow ozone to be applied to the water lines via the "clean water system" water bottle. Significant savings may be made by the resulting reduction in blockages of hand pieces, couplings, etc.

Prevention of demineralisation surrounding orthodontic brackets:

This is a well-recognised problem following fixed appliance treatment in orthodontic cases. Accumulation of cariogenic bacteria in bracketed areas can lead to demineralisation surrounding the bracket in patients where oral hygiene control is not meticulous. If demineralisation is allowed to take place, the optical properties of the tooth enamel will change, and white or coloured lesions will appear. By regularly eliminating the microorganisms, and supporting this with regular oral health care advice, these lesions may be avoided. Sadly, once the lesions have developed, remineralisation will not return the optical properties of the effected enamel to their original state.

Ozone treatment has the capability of preventing this presence of cariogenic bacteria and, if repeated at 8 to 14 week intervals GDP's and orthodontists have the potential to eliminate the possibility of any demineralisation occurring with its subsequent problems related to cosmetic appearance and susceptibility to decay. When used in a preventative role such as this, the application of ozone to the treatment area is performed for 10 seconds. Achieving a seal around many orthodontic brackets can be troublesome and again in this case the use of liquid rubber dam can prove invaluable. Applied in a circular fashion around the bracket it makes it relatively simple for the operator to seal and deliver the required ozone dose.

In conclusion, KaVo have received feedback from a large number of the 1500 dental practices who have purchased the Healozone up to 36 months ago. Many of these Dentists have described the HealOzone as an addition to their practice that they simply could now not live without. They describe the HealOzone as a win-win situation for their practice as well as for the Patients. Numerous dentists report earning the entire cost of the HealOzone within 2 months of use within their practice whilst ozone treatment is much less costly for Patients than traditional drill and fill techniques as well as being faster, painless, eliminates the cause of the problems and allows nature to remineralise their carious lesions via the patients own saliva.