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The Ozone Generators in Modern Dental Practice: A Comprehensive Narrative Review

[1]Akshatha S, Post Graduate, Pediatric and Preventive Dentistry, Coorg Institute of Dental Sciences, Virajpet, Karnataka

[2]Malvika P G, Reader, Pediatric and Preventive Dentistry, Coorg Institute of Dental Sciences, Virajpet, Karnataka

Corresponding Author: Akshatha S, Post Graduate, Pediatric and Preventive Dentistry, Coorg Institute of Dental Sciences, Virajpet, Karnataka

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Abstract

Ozone has emerged as a promising technology in dentistry due to advances in controlled ozone generation systems. Ozone (O_3), a highly reactive form of oxygen with a short half-life, must be generated on demand for clinical use. Dental ozone generators commonly employ ultraviolet radiation, corona discharge, or cold plasma techniques, each varying in efficiency, ozone yield, and safety. Medical-grade ozone is typically produced from pure oxygen to ensure stable concentration and minimize impurities. Modern generators incorporate features such as adjustable output controls, sealed delivery units, and scavenging systems to reduce ozone leakage and occupational exposure. Despite these technological developments, concerns regarding ozone toxicity, lack of standardized protocols, and variability among generator systems continue to limit widespread clinical acceptance. Regulatory and safety studies emphasize the need for controlled delivery and effective evacuation systems, particularly in open-system devices. This review discusses the principles of ozone generation, types of dental ozone generators, design characteristics, advantages, and safety considerations, highlighting the importance of proper device selection and safe integration of ozone technology into dental practice. A comprehensive understanding of ozone generator systems is essential for informed device selection, safe clinical use, and the responsible integration of ozone technology into dentistry.

Keywords: Ozone Generators, Dental Ozone Devices, Corona Discharge, Cold Plasma, Ozone Safety, Dental Technology, Generator Technology

Introduction

The growing emphasis on minimally invasive and biologically oriented dental care has led to increased interest in adjunctive therapeutic modalities that enhance antimicrobial efficacy while preserving healthy oral tissues. Ozone therapy has re-emerged in dentistry as a promising approach owing to its potent antimicrobial properties, ease of chairside application, and favourable patient acceptance.

The term "ozone" is derived from the Greek word ozein, which means "odour," a reference to its distinct, sharp smell. This name was first introduced in 1840 by the German chemist Christian Friedrich Schönbein, who is widely regarded as "The Father of Ozone Therapy". His research sparked interest in ozone's ability to purify air, disinfect water, and serve in medical treatments, shaping future advancements in ozone science [1].

Ozone (O_3) is a triatomic oxygen molecule with a high oxidation potential, enabling it to inactivate a broad spectrum of microorganisms, including bacteria, viruses, and fungi. Its antimicrobial action is primarily mediated through oxidative disruption of microbial cell membranes and intracellular components, resulting in rapid microbial cell death [2]. In addition to its disinfectant effects, ozone has been reported to improve local oxygen metabolism, modulate inflammatory responses, and support tissue healing through stimulation of antioxidant defense mechanisms [3].

In dental practice, ozone is generated using specialized ozone generators that convert molecular oxygen into ozone through corona discharge or ultraviolet radiation. Due to its short half-life, ozone must be produced at the point of use, allowing controlled and localized delivery in gaseous, aqueous, or oil-based forms. When applied within therapeutic concentrations and with appropriate safety measures, ozone exhibits selective toxicity toward pathogenic microorganisms while maintaining biocompatibility with oral tissues [4].

Ozone generators have been investigated across various dental specialties, including conservative dentistry, endodontics, periodontics, and oral surgery. Reported clinical applications include caries management, root canal disinfection, periodontal therapy, management of oral infections, and enhancement of post-operative wound healing. Despite encouraging in vitro and clinical evidence, variations in delivery methods and treatment protocols, along with concerns related to ozone inhalation toxicity, have limited its routine clinical use.

This article focuses on ozone generators used in dentistry, highlighting their underlying mechanisms, classification, advantages, limitations, and safety aspect.

Principle Of Ozone Generation

Ozone (O_3) is a highly reactive and unstable allotrope of oxygen that rapidly decomposes back to molecular oxygen, making storage impractical. Consequently, ozone intended for dental use must be generated immediately before application using chairside ozone generators [5]. The principle of ozone generation is based on the dissociation of molecular oxygen (O_2) into atomic oxygen, followed by the recombination of these atoms with intact oxygen molecules to form ozone [6].

In ozone generators, energy is supplied to oxygen molecules to overcome the strong covalent bond between the two oxygen atoms. This energy input causes molecular oxygen to split into free oxygen radicals. These highly reactive radicals subsequently combine with molecular oxygen to produce ozone. The amount of ozone generated is directly influenced by factors such as the intensity of energy applied, duration of exposure, oxygen purity, temperature, and humidity [2,6].

The stability of ozone is limited, with a half-life ranging from minutes to hours depending on environmental conditions. Higher temperatures and increased humidity accelerate ozone decomposition, whereas cooler and drier conditions favour greater stability. For this reason, dental ozone generators are designed to produce ozone at controlled concentrations and deliver it immediately after generation to minimize loss of potency [7].

Precise regulation of ozone concentration is a critical aspect of ozone generator design. Excessive concentrations may pose risks to both patients and operators due to ozone's oxidative potential, particularly upon inhalation. Modern dental ozone generators therefore incorporate electronic controls that allow adjustment of ozone output, flow rate, and exposure time, ensuring reproducibility and safety during use.

Understanding the fundamental principle of ozone generation is essential for the appropriate selection and operation of dental ozone generators. A clear knowledge of the physicochemical processes involved allows clinicians to appreciate stability, and safe delivery within the dental environment.

Types of Ozone Generators

Medical-grade ozone is produced exclusively from purified oxygen to ensure consistency and safety, as atmospheric air contains variable concentrations of oxygen and nitrogen along with trace gases. Environmental factors such as altitude, temperature, and pollution further influence atmospheric composition, making ambient air an unreliable source for controlled ozone generation. Consequently, dental and medical ozone generators are designed to produce ozone from pure oxygen under regulated conditions [8].

Based on the method of ozone generation, three primary systems are employed:

- **Ultraviolet (UV) System**

The ultraviolet system mimics the natural formation of ozone in the upper atmosphere, where ultraviolet radiation dissociates molecular oxygen. In this method, UV light at a wavelength of approximately 185 nm splits oxygen molecules (O_2) into individual oxygen atoms, which then combine with molecular oxygen to form ozone (O_3) [9].

This system generates relatively low ozone concentrations and is mainly used for air purification, aesthetic treatments, and sauna applications. Due to its limited ozone output, the UV system is less commonly utilized in dental and medical applications [8].

- **Corona Discharge System**

In the corona discharge system, oxygen is passed through a plasma field created by a high-voltage electrical discharge. The electrical energy dissociates oxygen molecules into atomic oxygen, which subsequently recombines to form ozone.

This method allows precise control of ozone concentration and produces ozone that is approximately ten times more soluble in water than oxygen. Owing to its efficiency, reliability, and ease of regulation, the corona discharge system is the most widely used method in medical and dental ozone generators[8]. According to the International Association of Certified Home Inspectors (InterNACHI), corona discharge systems are significantly more efficient than UV-based ozone generators [9].

- **Cold Plasma System**

The cold plasma system operates by ionizing oxygen gas at room temperature (approximately 20 °C) between two electrodes separated by a dielectric barrier. An electrostatic field is generated as voltage passes between the anode and cathode, leading to dissociation of oxygen molecules into atomic oxygen. These atoms then recombine with molecular oxygen to form ozone.

This system is capable of producing high ozone concentrations and is commonly employed in air and water purification. In dentistry, cold plasma technology is adapted for localized ozone generation at lower, controlled concentrations [8].

Dental Ozone Devices

Several commercially available dental ozone devices utilize the above generation principles, with variations in design, ozone output, and safety mechanisms.

- **HealOzone Device**

HealOzone was developed by CurOzone Inc. (Canada) and is currently licensed to KaVo Dental GmbH (Germany). The technology was initially pioneered at Queen's University Belfast and Barts and The London School of Medicine and Dentistry [9]. The device holds the Conformité Européenne (CE) mark for the treatment of occlusal, fissure, and root caries, although it has not yet received approval from the United States Food and Drug Administration [10]. HealOzone utilizes a corona discharge system to generate high-concentration ozone at approximately 2100 ± 200 ppm, which is delivered directly to the affected tooth using sealed silicone cups with an inbuilt scavenging system to prevent ozone leakage. Any residual ozone is neutralized within the system [11]. However, due to the size of the delivery cups, access to certain areas of the oral cavity may be limited. Treatment duration typically ranges from 20 to 120 seconds and is followed by application of a reductant such as fluoride, calcium, zinc, phosphate, or xylitol, along with a take-home oral care kit [10].

Clinical evidence regarding HealOzone demonstrates mixed results. Randomized controlled trials have shown variable outcomes in the management of non-cavitated carious lesions, while small-scale studies on root caries suggest some degree of effectiveness[12]. However, these studies are limited by small sample sizes and potential bias. In 2005, the National Institute for Health and Clinical Excellence (NICE) concluded that available evidence was insufficient to recommend the routine clinical use of HealOzone outside well-designed clinical trials. The initial cost of the HealOzone device is approximately £11,950 (≈ ₹12,67,700), with a per-tooth treatment cost ranging from £18 (≈ ₹1,908) to £21 (≈ ₹2,226), excluding maintenance and servicing costs [12].

- **OzonyTron Device**

Another commercially available device is OzonyTron, a tabletop cold plasma ozone therapy unit that operates using an open-system configuration. OzonyTron delivers ozone at comparatively lower concentrations of approximately 525 ppm, thereby reducing the risk associated with minor gas leakage [13,14]. The device is available in multiple models, including X, XL, XO, XP/OZ, and XPO, and ozone output can vary from 1,000 to 100,000 ppm depending on the electrode and selected settings. It utilizes a double-glass probe filled with noble gases, which emits electromagnetic energy when activated, cleaving atmospheric diatomic oxygen into atomic oxygen and ozone at the point of contact with the tissue. The device is operated using a foot pedal and is compatible with a universal voltage range of 100–240 V AC.

OzonyTron is considered non-invasive and painless and has demonstrated strong antiseptic properties. It has been used for the management of conditions such as lip herpes, post-surgical wounds, facial skin inflammation, seborrhoea, and toenail fungal infections. The device is also reported to promote faster healing, reduce inflammation, and enhance local blood flow through stimulation of growth factors [15]. Clinical evidence supporting its efficacy includes findings by Skomro et al., who reported beneficial effects in dermatological and post-surgical conditions, and Vukovic M, who supported its role in dental wound healing and inflammation management. While official pricing details are not widely available, a used OzonyTron unit manufactured in 2018 was listed at approximately 261,880 Ukrainian Hryvnias (≈₹5,76,000) [15,16]. HealOzone mainly targets dental caries using sealed ozone delivery, whereas Ozytron has broader antiseptic applications with plasma-generated ozone delivery. (Table. I)

Table 1: Comparison between HealOzone and Ozytron

Feature	HealOzone	OzonyTron
Ozone Source	Sealed ozone gas at ~2100 ppm	Plasma-generated ozone, 1,000–100,000 ppm
Application Target	Caries treatment (pits, fissures, roots)	Broad antiseptic use: wound healing, ulcers
Delivery Method	Sealed silicone cups & vacuum return	Plasma electrodes, nozzles, trays
Clinical Evidence	Mixed RCT results; NICE does not recommend broadly	Observational evidence; small-scale positive report
Safety	Safe in sealed use; concerns with leaks	Safe, non-invasive; widely used in Europe

Other Dental Ozone Devices

- **Prozone (W&H):** Designed for endodontic and periodontal use and allows preset tissue-compatible ozone dosages based on treatment indication. The device features exchangeable plastic tips to ensure hygienic application and facilitate precise pocket gassing, with an approximate cost ranging from ₹5,000 to ₹10,000 [8].
- **Ozotop:** Ozotop is a compact tabletop ozone unit that employs a free-flow delivery system using corona discharge technology. In this device, ambient air is filtered and dried before passing over a ceramic plate, where high voltage generates ozone. As it is an open-system device, high-volume suction is required during use. Ozone application times vary depending on the indication, ranging from 6 seconds for basic disinfection to 24 seconds for deep periodontal or surgical disinfection [8].
- **OZI-Cure Device**: It is a recently introduced ozone therapy unit designed to deliver lower ozone concentrations through an open-system configuration, eliminating the need for an internal scavenging unit. Its simplified delivery system and compact design enhance usability for routine dental and minor surgical procedures [17].
- **Customized Thermoformed Dental Appliances**: It has been developed for localized ozone gas application to gingival tissues. These appliances include gas inlet and outlet ports to ensure complete sealing, thereby enhancing targeted delivery and reducing gas leakage, making them safer than conventional open ozone delivery systems[18].

Safety Considerations

Safety is a major concern in the use of ozone generators due to the strong oxidative and respiratory irritant properties of ozone. Inhalation of ozone, even at low concentrations, may cause irritation of the respiratory tract and pose risks to both patients and dental personnel. Therefore, strict control of ozone generation and delivery is essential in dental settings.

Dental ozone generators are designed to limit occupational exposure by regulating ozone concentration and ensuring localized delivery. Closed or sealed systems with built-in scavenging mechanisms are considered safer, as they actively evacuate residual ozone after application. In contrast, open-system devices lack internal evacuation and may allow ozone leakage into the operatory environment, increasing the risk of exposure. For such systems, the use of high-volume suction and adequate ventilation is mandatory.

Millar et al. conducted a comparative safety assessment of dental ozone delivery devices and reported that systems with built-in scavenging mechanisms, such as Heal Ozone, maintained ambient ozone concentrations within permissible exposure limits, whereas open-system devices like Ozi-Cure exceeded safety thresholds when adequate suction was not employed. These findings highlight the importance of device design, operator training, and strict adherence to recommended safety protocols when using ozone generators in dentistry [11,17].

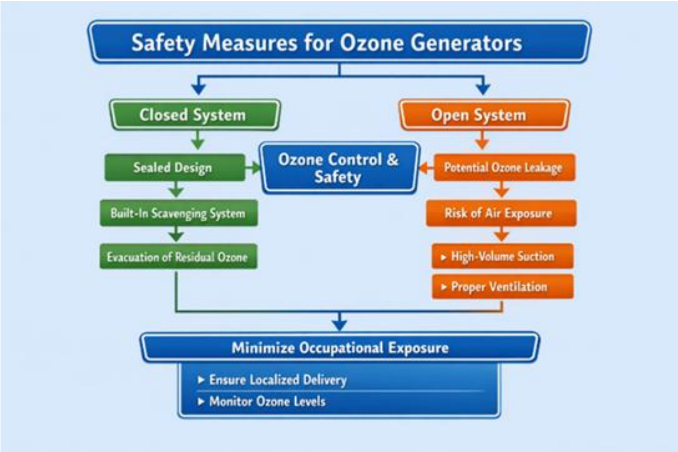

Figure 1: Safety measures and ozone exposure control in closed and open ozone generator systems.

Advantages of Ozone Generators

1. **Chairside Production** – Ozone generators allow on-site production of ozone, eliminating the need for storage and ensuring freshness.
2. **Precise Control** – They provide accurate regulation of ozone concentration and exposure time for controlled clinical application.
3. **Compact Design** – The devices are compact and user-friendly, allowing easy integration into routine dental practice.
4. **Enhanced Safety Features** – Modern ozone generators include regulated output systems and scavenging mechanisms to minimize occupational exposure.
5. **Reduced Risk of Microbial Resistance** – Ozone acts through oxidative mechanisms rather than targeting specific biochemical pathways, thereby not inducing microbial resistance.
6. **Efficient Adjunctive Technology** – These characteristics make ozone generators a safe, controlled, and effective adjunct in dental therapy.

Limitations and Challenges

Despite technological advancements, several limitations restrict the widespread adoption of ozone generators in dentistry. One major challenge is the lack of standardized protocols regarding ozone concentration, exposure duration, and delivery parameters across different devices. Variability in ozone output among generators can lead to inconsistent performance and raises concerns regarding reproducibility and safety.

Another limitation is the potential risk of ozone toxicity if devices are improperly used or maintained. Open-system generators, in particular, require stringent control measures to prevent occupational exposure. Additionally, the cost of ozone generator units, maintenance requirements, and the need for specialized training may limit their routine use in clinical practice.

From an evidence-based perspective, regulatory and advisory bodies have expressed caution. The National Institute for Health and Clinical Excellence (NICE) concluded that available evidence was insufficient to support routine clinical use of ozone-based technologies beyond controlled research settings. Furthermore, long-term data on occupational exposure and cumulative effects of ozone use in dental environments remain limited. These challenges underscore the need for standardized guidelines, improved device design, and further high-quality research before ozone generators can be universally integrated into dental practice.

Conclusion

Ozone generators enable controlled, chairside production of medical-grade ozone for dental use. Advances in device design have improved precision and safety; however, variability among systems and concerns regarding occupational exposure persist. Standardized protocols, improved safety mechanisms, and further research are essential for the safe and effective integration of ozone generator technology into dental practice.

Abbreviations

NICE- The National Institute for Health and Clinical Excellence

RCT- Randomized Control Trial

Ppm-parts per million

CE-Conformite Europeenne

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