



Ozonated Water Decreases *In vitro* Contamination at Dental Implant Interface in Different Connections

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Cases of peri-implant diseases have increased, highlighting the need for preventive and therapeutic protocols. This study aimed to evaluate the effectiveness of ozonated water on *In vitro* decontamination of implant-abutment interfaces in external hexagon (EH) and morse cone (MC) connections.

Study Design: *In vitro* study.

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Place and Duration of Study: Sample: Department of Periodontics and Implant Dentistry of Ingá University Center – UNINGÁ, between June 2020 and December 2021.

Methodology: Twenty-four implant-abutments (IA) in EH (n=12) and MC (n=12) connections were divided into groups: negative control (NC) – sterile IA; positive control (PC) – IA contaminated with biofilm; and ozone (O) – IA contaminated with biofilm and decontaminated with ozonated water (60µg/mL, 1min). The effectiveness of ozonated water was evaluated by counting colony-forming units (CFU/mL), and both connection types were compared.

Results: There was a significant difference among groups in both connection types, outside and inside the implants ($P=0.000$). Group O showed a significant decrease in CFU/mL compared to group PC outside and inside the implants for EH and MC connections ($P=0.000$). Only group O in the EH connection presented a significant difference in CFU/mL compared to outside and inside the implants ($2.475 \times 10^3 \pm 0.320$ and $1.775 \times 10^3 \pm 0.125$, respectively) ($P=0.033$). Comparison between connections was statistically different for groups PC and O, outside and inside the implants ($P=0.000$).

Conclusion: Ozonated water showed effectiveness *in vitro* decontamination of implant-abutment interfaces in both connection types.

Keywords: Dental implant-abutment interface; ozone; decontamination; biofilm.

1. INTRODUCTION

Dental implant treatment is an admittedly successful reality, and this rehabilitation treatment modality has been widely used with the success of implants [1]. Consequently, it is natural that there is also an increase in problems related to this therapy [2].

Peri-implant mucositis is a complication frequently found in dental implant rehabilitation [3], reaching up to 80% of patients [4,5]. It is a reversible inflammatory reaction that affects peri-implant tissues in which it is necessary to remove the biofilm to restore peri-implant health conditions [6]. Although peri-implant mucositis is a more easily controllable condition once the primary etiologic agent is removed, biofilm [6,7], it is considered a precursor of peri-implantitis [4,7], a much more complex clinical condition that affects peri-implant tissues in a not reversible way, causing progressive loss of supporting bone [7].

Therefore, individuals diagnosed with peri-implant mucositis can evolve into peri-implantitis, especially in the absence of adequate control [7]. As stated before, peri-implantitis is an irreversible and complex condition [8]. Once there is no consensus about a gold-standard protocol to treat peri-implantitis [9, 10], peri-implant mucositis control and treatment become imperative to maintain peri-implant tissue health and implants in long-term function.

In this scenario, the implant-abutment interface deserves special attention due to it being a

region that facilitates biofilm accumulation [11]. Despite advances in implant and component manufacturing methods that allow greater precision in interface adjustment, this region still has micro gaps that enable the entry of microorganisms in all connection types when submitted to mastication forces [12]. According to the literature, Morse cone connection implants present less bacterial penetration than external and internal hexagon connection implants [13].

Peri-implant mucositis treatment depends on the debridement of the implant surface and implant-abutment interface using mechanical methods such as curettes, ultrasound devices, and abrasive powders jets [9,14,15], or antimicrobial agents such as chlorhexidine [9,16], tetracycline, and antimicrobial photodynamic therapy [3,10,14].

Considering the peculiarities and characteristics of dental implants, there is a need to employ a decontamination therapy that reduces bacterial adherence without causing major changes to the implant surface and is effective in resolving inflammation and preserving peri-implant tissues [17]. Among the available antimicrobial agents, ozone has emerged as an alternative; however, few studies are related to peri-implant diseases.

Ozone (O₃) is a potent oxidizing agent with antimicrobial activity due to releasing reactive oxygen species (ROS). The rapid microorganism's inactivation is one of its outstanding characteristics [18], proving effective in dental treatments [19,20]. Ozone has an antimicrobial effect on bacteria, viruses, and

fungi, as well as immunomodulatory, anti-hypoxic, biosynthetic, and anti-inflammatory properties [21]. In times of bacterial resistance, it emerges as an attractive antimicrobial option that does not present toxicity or side effects unless aspirated [22].

Ozone is available in some presentation forms [23], and ozonated water is considered the most predictable alternative to gas or oil due to the greater practicality of use, application control, and lower risk of toxicity [24].

Similar efficiencies were found in both therapies when compared to antimicrobial photodynamic therapy (association of a low-level laser and a photosensitizer that also generates ROS) in periodontal treatment, concluding that ozone is a valuable adjuvant in non-surgical periodontal treatment [25]. In a clinical study, peri-implantitis treatment was performed with regenerative therapy, and ozone was used in gaseous form as an adjunct treatment after mechanical decontamination methods, with significant clinical and radiographic improvements [26]. Also, in a recent systematic review [23], despite the heterogeneity of the studies, ozone showed encouraging therapeutic effects with regard to periodontal and peri-implant diseases.

Therefore, the present study aimed to evaluate the effectiveness of ozonated water on *in vitro* decontamination of implant-abutment interfaces in external hexagon and morse cone connections.

2. MATERIALS AND METHODS

This study was approved by the Research Ethics Committee of the Inga University Center (protocol number 4.444.416) for the use of subgingival biofilm. The biofilm was frozen and stored at the Inga University Center Microbiology Laboratory [14].

A sample size calculation was performed based on an alpha significance level of 5% (0.05) and a beta of 20% (0.20) to achieve 80% power of the test to detect a minimum difference of 3.5×10^6 CFU/mL with a standard deviation of 1.49×10^6 for the colony-forming units (CFU/mL) [14,15], which verified the need of twenty-four implant-abutments (IA) used in this study.

Twelve grade IV titanium implants, external hexagon connection (EH), surface treated with double acid etching, cylindrical, measuring 4.1

mm in diameter and 13mm in length (Classic-CI-Systhex® – Curitiba/Brazil), and twelve EH abutments, straight, measuring 4.1mm in diameter and 2mm in transmucosal height (Systhex® – Curitiba/Brazil); twelve grade IV titanium implants, morse cone connection (MC), surface treated with double acid etching, cylindrical, measuring 4.3mm in diameter and 13mm in length (Attract-Systhex® – Curitiba/Brazil), and twelve MC abutments, straight, measuring 4.5mm in diameter and 2.5mm in transmucosal height (Systhex® – Curitiba/Brazil). Both implants and abutments were sterilized at the factory.

In a flow chamber, using gloves and sterile instruments, the abutments were installed in the respective implants and screwed with torque recommended by the manufacturer, 32N for EH and 20N for MC. Then, IA was distributed in the following experimental groups:

- NEGATIVE CONTROL (NC): sterile IA in EH (n=4) and MC (n=4) connections.
- POSITIVE CONTROL (PC): IA contaminated with subgingival biofilm in EH (n=4) and MC (n=4) connections.
- OZONE (O): IA contaminated with subgingival biofilm and treated with ozonated water in EH (n=4) and MC (n=4) connections.

After unfrozen, biofilm was cultivated in sterile brain heart infusion (BHI) broth (Kasvi – São Jose dos Pinhais/Brazil). The IA from groups PC and O were contaminated *in vitro* in test tubes containing 10mL of broth containing subgingival biofilm and maintained for seven days in a 37°C oven for biofilm formation on interfaces. All procedures were performed in a laminar flow chamber, using gloves and sterile instruments to avoid contamination outside the experiment. The IA from group NC remained sterile and were placed in a sterile broth in an oven at 37°C for seven days for factory sterility certification.

After seven days, sterile absorbent paper cones (Tanari® – Manacapuru/Brazil) were used to collect the biofilm from the implant-abutment interface region. After abutment removal, this collection was performed in the outer region of the implant/abutment interface (outside) and inside the implants (inside). The paper cones were used for seeding in Petri dishes containing culture medium (Laborclin® – Pinhais/Brazil).

In group O, decontamination was performed with ozonated water before collection. For ozonated

water preparation, a Medplus ozone generator MX (Philozon® – Camboriu/Brazil) was used, with electronic regulation, medical oxygen (99.5%, White Martins® – Rio de Janeiro/Brazil), cooled double-distilled water (SanobioI® – Pouso Alegre/Brazil) and the ozone was diluted in a specific glass column (Philozon® – Camboriu/Brazil). The equipment was calibrated at a concentration of 60µg/mL, its maximum capacity [27]. However, according to the manufacturer, only 20% of the ozone is fixed in the water. In this sense, it is estimated that the real concentration of ozone in the ozonated water used was around 12µg/mL [28].

The IA were then immersed in microtubes (Axygen® – São Paulo/Brazil) containing 2mL of ozonated water, where it remained for 1 minute with the microtubes covered. Group O collection was also performed using sterile absorbent paper cones (Tanari® – Manacapuru/ Brazil), following the above-mentioned steps. As well as the collection of implants from groups PC and NC.

All seeded plates were stored in a CO₂ jar, simulating anaerobiosis and ensuring a microaerophilic condition. They were then waited 48 hours in an oven at 37°C to allow colony growth. From this, the colony-forming units

(CFU/mL) were counted with the naked eye by an experienced and calibrated examiner (M.A.L.O). Fig. 1 illustrates the sequence of the experimental technique.

As the EH and MC implants had different diameters, the circumference of these implants was calculated (Formula: $C=2\pi r \rightarrow HE = 12.874\text{mm}$ e $MC = 13.502\text{mm}$), and the results of the MC implants were parameterized with the EH implants. For all groups, a Shapiro-Wilk normality test was performed. The intergroup comparison was performed by one-way analysis of variance (ANOVA) and Tukey's post-test. Comparisons between connection types and inside and outside the implants were done using the independent t-test, with a significance level of 5%.

3. RESULTS

Intergroup comparison showed a statistically significant difference among all groups in two connection types outside and inside the implants ($P=.00$). Group O showed a significant decrease in CFU/mL compared to group PC outside and inside the implants ($P=.00$), showing values of 2.475×10^3 (outside), 1.775×10^3 (inside), and 0.157×10^3 (outside), 0.123×10^3 (inside) for EH and MC connections, respectively (Fig. 2).

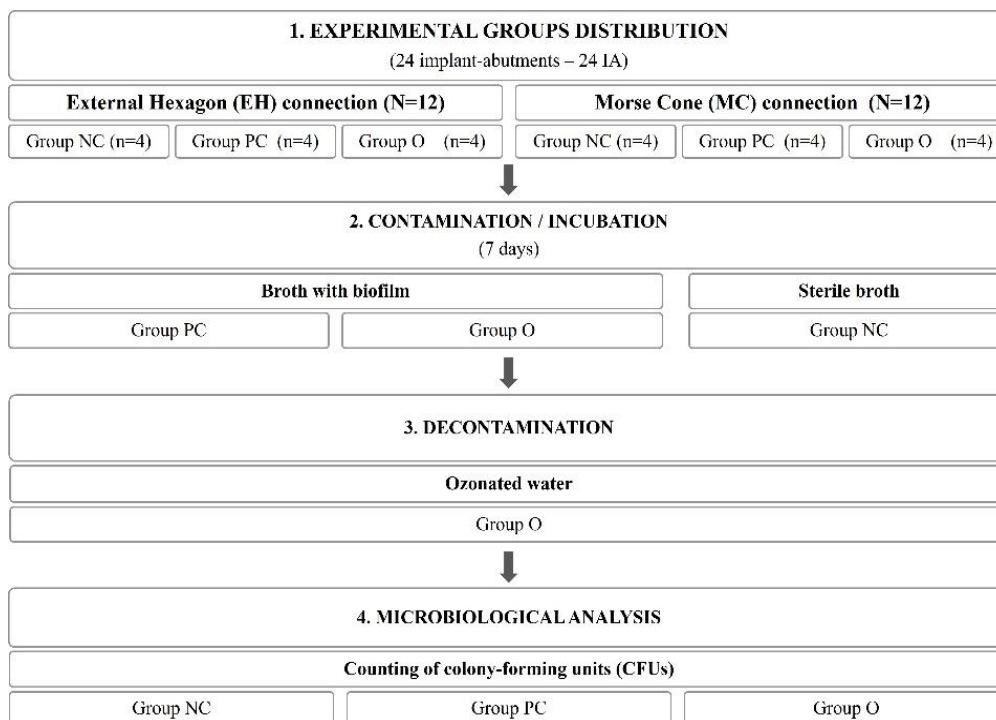


Fig. 1. Flowchart of experimental groups distribution and technique

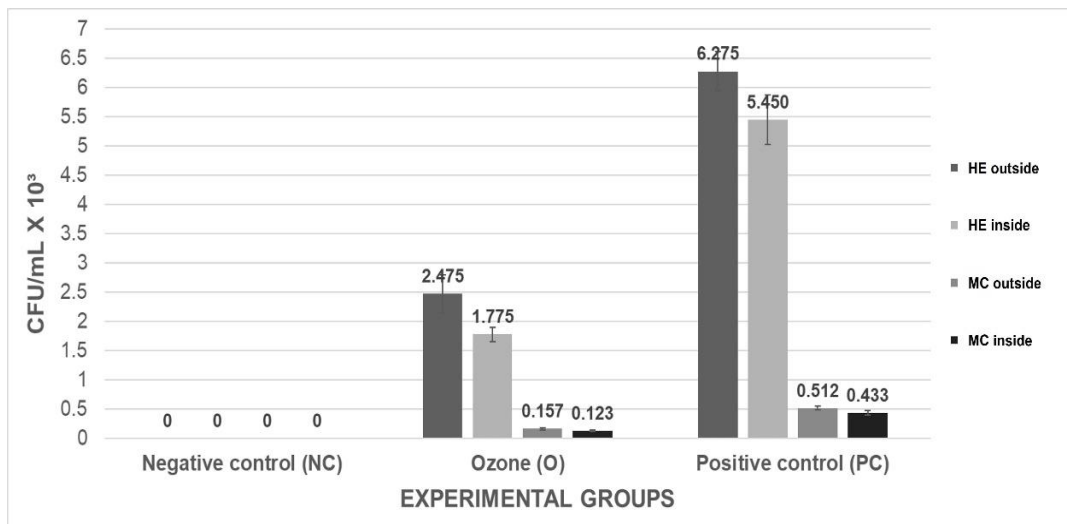


Fig. 2. Distribution of CFU/mL means and standard deviations obtained in the experimental groups for each connection type, outside and inside the implants (ANOVA and Tukey's post-test, $p < .05$)

In intragroup comparison, outside and inside the implants, in the same connection type, only group O in EH connection showed a statistically significant difference in the number of CFU/mL ($P = .03$) (Table 1). The comparison between the two connection types was statistically different for groups PC and O, outside and inside the implants ($P = .00$) (Table 2), demonstrating the greater contamination in EH connections and the potential for decontamination of the ozone outside and inside the implants on IA interface.

4. DISCUSSION

This study demonstrated that ozonated water decreased the number of CFU/mL at the implant-abutment interface in both connection types and also reduced the number of CFU/mL inside the external hexagon connection implants. These findings signal the potential of ozone as an adjunctive method for the prevention and treatment of peri-implant diseases.

As reported in previous studies [21,25,26,29,30], ozone has antimicrobial potential; however, as far as we know, studies related to peri-implant diseases are still scarce. Therefore, this study

focused on the decontamination of the implant-abutment interface, which is a critical region for biofilm accumulation [11]. This accumulation leads to the development of peri-implant mucositis which, if not treated correctly [7], can evolve and compromise peri-implant bone [7,11].

In this sense, finding a method that is effective and easy to apply not only in peri-implant mucositis treatment but also that can be used in peri-implant supportive therapy is important, aiming the maintenance of peri-implant tissue health and as a way of preventing peri-implant diseases.

In this study, ozone showed good antimicrobial action, reducing the number of CFU/mL compared to group PC, although it did not eliminate microorganisms from the interfaces. These results agree with Hauser-Gerspach et al. and Isler et al., who obtained good efficacy from ozone in gas form when decontaminating implant surfaces [26,29]. Indeed, it is difficult to perform complete decontamination on these surfaces due to, among other factors, implants' macro and microgeometry.

Table 1. Mean values and standard deviations of CFU/mL on comparison outside and inside the implants in the same connection type (independent t-test)

Groups	Outside	Inside	P
PC (EH)	$6.275 \times 10^3 \pm 0.340$	$5.450 \times 10^3 \pm 0.420$	0.08
O (EH)	$2.475 \times 10^3 \pm 0.320$	$1.775 \times 10^3 \pm 0.125$	0.03*
PC (MC)	$0.512 \times 10^3 \pm 0.031$	$0.433 \times 10^3 \pm 0.036$	0.09
O (MC)	$0.157 \times 10^3 \pm 0.022$	$0.123 \times 10^3 \pm 0.015$	0.17

* Statistically significant at $P < .05$

Table 2. Mean values and standard deviations of CFU/mL on comparison between the two connection types, outside and inside the implants (independent t-test)

Groups	EH	MC	P
PC (outside)	6.275x10 ³ ± 0.340	0.512x10 ³ ± 0.031	0.00*
PC (inside)	5.450x10 ³ ± 0.420	0.433x10 ³ ± 0.036	0.00*
O (outside)	2.475x10 ³ ± 0.320	0.157x10 ³ ± 0.022	0.00*
O (inside)	1.775x10 ³ ± 0.125	0.123x10 ³ ± 0.015	0.00*

* Statistically significant at $P < .05$

In spite of ozone has some forms of application [23,31,32], in this study, ozonated water was chosen due to its easy application and greater safety than gas form [23,31], for example. From a clinical point of view, ozonated water would be more interesting for peri-implant diseases treatment since this form can be used as an irrigation agent, inside the peri-implant sulcus, as an adjunct therapy in peri-implant mucositis treatment, or even applied in surgical procedures during peri-implantitis treatment, avoiding the dissipation that would occur with the use of the gas form [27].

Considering decontamination by ozone, concentration is also an important parameter. The literature says that the greatest antimicrobial effect of ozone is related to its concentration; the greater the concentration, the greater the effect [32]. The increase in application time does not appear to improve its antimicrobial effects [32]. Considering this information and based on previous studies from our research group [27,28], this study used a concentration of 60µg/mL, the maximum concentration offered by the used equipment.

Furthermore, according to the manufacturer, only 20% of the ozone that leaves the equipment is fixed in the water [28]. Therefore, it is estimated that the concentration applied on the interfaces was 12µg/mL. Tonon et al. used a final concentration of 7.24µg/mL and obtained good antimicrobial action against biofilms, even with a lower ozone concentration in the water [32]. This limitation can be important in clinical use due to the difficulty in maintaining ozone concentration to deliver it to a specific site or needed area.

Temperature and pH also have an important effect on ozone concentration in water. Gas degradation rates increase with increasing temperature and pH of the medium [32]. For this reason, the water used was stored in a refrigerator at 4°C for the experiment, and the ozonated water was used immediately after

preparation for the decontamination of the interfaces. The water used in this study has a pH of around 5 to 7, as informed by the manufacturer.

As expected, the EH connection was more contaminated. The microorganism's capacity of penetration inside the implants was also higher in the EH connection compared to the MC connection. These results agree with those found by Canullo et al. in their study with patients [12].

As for the ozone penetration potential decontaminating the interior of the implants, only the EH connection had a good result, significantly reducing the number of CFU/mL inside the implants. Although this difference may have occurred due to the greater contamination in EH, this finding is quite interesting since it can improve the predictability of this implant in the oral cavity, offsetting a possible disadvantage compared to the morse cone connection in terms of microorganism accumulation and penetration.

As an *in vitro* study, some limitations must be stated to collaborate with research in the field. First of all, *in vitro*, this study demonstrated a good antimicrobial effect of the ozonated water with the possibility of being tested in a clinical scenario. However, that is future research, and with the results presented here, it is not possible to state its effects in a clinical context. Also, this study did not compare ozonated water with other decontaminating agents, which is important in future *in vivo* research.

5. CONCLUSION

Considering this proposal's limitations and pioneering spirit, it was possible to conclude that the ozonated water presented good efficacy on *in vitro* decontamination of implant-abutment interfaces in external hexagon and morse cone connections. The good results presented here encourage future research in order to develop a

truly effective clinical application protocol using ozone for treating and preventing peri-implant mucositis.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

CONSENT

It is not applicable.

ETHICAL APPROVAL

Approved by the Research Ethics Committee of the Inga University Center, number 4.444.416.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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