Sodium Bicarbonate Jet Reduces Contamination of Dental Implants In Vitro Without Causing Visible Surface Changes

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Purpose: The increasing use of dental implants in oral rehabilitation has contributed to the increase of cases of peri-implantitis, a complex clinical condition that persists without an ideal treatment protocol. Therefore, this study aimed to verify the decontaminating action of the sodium bicarbonate jet in vitro, using different protocols, and the presence of visible changes on the surface of dental implants. Materials and Methods: Sixteen titanium implants (BioHE, Bioconnect) were used, divided into four groups (four implants per group): sterile implants (S)—negative control; implants contaminated with oral biofilm (C)—positive control; and implants contaminated with oral biofilm and decontaminated with a sodium bicarbonate jet for 30 seconds (J30) or 60 seconds (J60). The implants of groups C, J30, and J60 were contaminated in vitro with oral biofilm, then groups J30 and J60 received the respective decontamination treatments. Microbiologic analysis was performed by counting the colony-forming units (CFUs), and a qualitative descriptive analysis of the implant surface was performed after microbiologic analysis using scanning electron microscopy (SEM). Statistical analysis included one-way analysis of variance (ANOVA) and Tukey tests and the independent t test, with a .05 significance level.

Results: There was a significant reduction (P < .01) in the number of CFUs in groups J30 (3.63 × 10⁶ ± 0.32) and J60 (2.74 × 10⁶ ± 0.21) compared with group C (5.05 × 10⁶ ± 0.43). Both decontaminated groups were statistically different from group S, which did not show bacterial growth (P < .01). When groups J30 and J60 were compared, there was also a significant difference between them (P < .01), and the group J60 showed greater decontaminating potential. The descriptive qualitative analysis did not show any visible changes on the surface of the implants. Conclusion: The sodium bicarbonate jet was effective in decontaminating titanium implants in vitro, causing no visible damage to the implant surface. Int J Oral Maxillofac Implants 2022;37:587–592. doi: 10.11607/jomi.9338

Keywords: decontamination, dental implants, peri-implantitis, scanning electron microscopy, sodium bicarbonate

Currently, dental implants are widely used as a modality of rehabilitation therapy for partially or totally edentulous patients,1,2 presenting as a safe alternative with high success rates.2 This accessibility to implant treatments has led to an increasing trend in the emergence of biologic complications related to this therapy, commonly known as peri-implant diseases.3,4

Among these conditions, peri-implantitis stands out, as it is clinically complex and irreversible, defined as a pathology related to the biofilm accumulation in the tissues around the implant, characterized by inflammation of the peri-implant tissues and progressive loss of support bone.5 Biofilm is considered the main etiologic factor of peri-implantitis, and the inflammatory response and host/parasite imbalance seem to be the key in the pathogenesis of tissue destruction, which defines the disease.6

In view of the importance of the presence of biofilm in the development of peri-implantitis, its removal from implant surfaces becomes vital for its treatment.7–9 The literature suggests that success in peri-implantitis treatment is related to implant surface decontamination, eliminating bacteria and their endotoxins, and thus stopping the disease progression.1,10,11

In this context, several ways to decontaminate the implant surface are listed in the literature, as well as associations between the chemical and mechanical methods presented,1,6,10–14 still without defining a clinical protocol for the treatment of peri-implantitis.6,12

Considering mechanical debridement, there are several possibilities through the use of curettes, ultrasound,
titanium brushes, and abrasive powder jets. The equipment with abrasive particle blasting under pressure is described in the literature as one of the possibilities for the mechanical decontamination of implants affected by peri-implantitis. Abrasive water and powders combined with pressurized air delivered by the high-pressure equipment result in production of mechanical abrasion that, when directed at the implant surface, removes the attached biofilm.

In addition to studies related to the decontaminating potential of abrasive powder jets, the literature also presents studies investigating the possibility of undesirable effects on the titanium surface when using such equipment. The powder, equipment parameters, and jet application time are some of the points discussed in relation to this method for implant surface decontamination. This kind of approach is especially studied because it is important to prevent damages to the implant surface. Adverse surface alterations caused by decontamination methods can contribute to accumulation of biofilm on the implant surface and affect the biocompatibility of the treated surface.

In view of the questions that remain about the use of the abrasive powder jet on the titanium surfaces and its real decontamination power, the present study aimed to verify the decontaminating action of the sodium bicarbonate jet in vitro, using different protocols, and the presence of visible changes caused to the dental implant surface.

**MATERIALS AND METHODS**

The sample size calculation was 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 $3.5 \times 10^6$ colony-forming units (CFUs) with a standard deviation of $1.49 \times 10^6$, showing the need for four implants in each group. Therefore, 16 Grade IV commercially pure titanium implants, surface treated with double acid attack, cylindrical, external hexagon type, measuring 5 mm in diameter × 18 mm in length, sterilized at the manufacturer, were used in the experiment (BioHE, Bioconnect).

**Experimental Groups**

All dental implants were randomly assigned to the following groups (n = 4) by a simple distribution:

- **Group S** (negative control): Sterile implants.
- **Group C** (positive control): Implants contaminated with oral biofilm.
- **Group J30**: Implants contaminated with oral biofilm and treated with a sodium bicarbonate jet for 30 seconds.
- **Group J60**: Implants contaminated with oral biofilm and treated with a sodium bicarbonate jet for 60 seconds.

**Microbiologic Analysis**

**Contamination of implant surfaces.** To contaminate the dental implant surfaces, an oral biofilm sample was used, which was frozen and was part of the sample of the Microbiology Laboratory of the Ingá University Center, UNINGÁ (Research Ethics Committee of UNINGÁ, approval no. 3.072.210). It is a subgingival biofilm collected from a patient diagnosed with periodontitis. After the biofilm was thawed and reactivated, the implants were contaminated in vitro, immersed in Brain Heart Infusion (BHI) sterile broth (Kasvi) containing the oral biofilm, and distributed into groups C, J30, and J60.

**Decontamination of implant surfaces.** The implants of groups J30 and J60 were brushed using a soft bristle toothbrush (Dentalclean) and 20 mL of sterile saline (Eurofarma). Twenty brush strokes were performed, covering all implant surfaces to remove excess biofilm. Subsequently, all implant faces were treated with a sodium bicarbonate jet, immobilized by titanium forceps (Fig 1), with movements from cervical to apical, rotating it on its axis for 30 seconds (J30) or 60 seconds (J60) with 60 psi air pressure and 14 psi water pressure (Jetlaxis Sonic, Schuster) and 125 µm powder granulometry (Airon, Maquira). Then, they were rinsed with 10 mL of sterile saline (Eurofarma) to remove dust particles on the surface.

**Sowing and counting of CFUs.** The implants of all groups were then inserted in 10 mL of sterile BHI broth. After 24 hours in an oven at 37°C, dilutions and sowing in acrylic plates containing culture medium, in duplicate, were performed. The plates were stored in a CO2 jar to simulate anaerobiosis, guaranteeing a condition of microaerophilia, and waited 48 hours in an oven at 37°C to allow the growth of the colonies. The seeded plates...
were used to count the CFUs, with the naked eye, by a calibrated and experienced examiner (M.A.L.O.).

Statistical Analysis
The normality of the data was assessed by the Shapiro-Wilk test. To compare the CFUs among the four experimental groups, the one-way analysis of variance (ANOVA) and Tukey tests were used. The comparison of the CFUs between the two groups that received treatment was performed with the independent t test. The tests were performed with the Statistica software (Statistica for Windows version 10.0, StatSoft). The data were considered significant at $P < .05$.

Scanning Electron Microscopy Analysis
After the microbiologic analysis, the implants were stored in 10% formaldehyde (Quimidrol) for 15 days. After this period, they were prepared for scanning electron microscopy (SEM). The dehydration sequence was started with ammonia in concentrations of 50%, 70%, 90%, and 100%, 1 hour in each concentration. The implants were transferred to identified stubs and remained stored in a plastic box with silica, for 48 hours, for drying before metallization, performed with 24k gold, in the metallizer (Denton Vacuum Desk IV) of the Institute of Science and Technology (ITC CEOSP Nanotec).

Then, the implants of the control and test groups were analyzed in a scanning electron microscope model JSM-5910 (JEOL) of the Institute of Science and Technology (ITC CEOSP Nanotec). The microscope was set at 15 kV with increases of ×500, ×2,500, and ×5,000. Each implant received reading fields distributed in its coronal, middle, and apical portions, with nine fields per portion randomly acquired.

Descriptive Qualitative Analysis
The descriptive qualitative analysis was performed by a single researcher (S.S.) calibrated and blinded to the experiment, from the images obtained from the three fields, with the naked eye. The parameters evaluated were damage to the implant surface, such as fractures and cracks and changes in the surface pattern compared with the control groups.

RESULTS

Microbiologic Analysis
There was a statistically significant difference in the number of CFUs among the four groups evaluated, with a reduction in the count of CFUs in groups treated with the sodium bicarbonate jet for 30 seconds ($3.63 \times 10^6 \pm 0.32$) and 60 seconds ($2.74 \times 10^6 \pm 0.21$) in relation to the contaminated control group ($5.05 \times 10^6 \pm 0.43$; $P < .01$). Even obtaining better results than group C, groups J30 and J60 could not completely eliminate the microbial biofilm from the implant surfaces.

The two test groups, when compared separately, were also statistically different, with the J60 group presenting the greatest decontaminating action ($2.74 \times 10^6 \pm 0.21$; $P < .01$).

SEM Analysis
In general, in the observation and comparison of the images, there were no changes on implant surfaces in the augmentations used for evaluation. There was no presence of fractures and cracks or visible changes in the test group surface pattern compared with the control groups. Representative images of the experimental groups, obtained by SEM, can be seen in Fig 2.

DISCUSSION
This study demonstrated a good decontaminating potential of the sodium bicarbonate jet used in vitro, without visible damage caused to the dental implant surface.

Since it is clinically complex, peri-implantitis still lacks an ideal treatment protocol. A factor contributing negatively to this treatment’s success is bacterial colonization on the implant surface that presents irregularities, configuring a framework that can hinder access for decontamination. In this scenario, this decontamination is especially delicate since it represents the key point in the treatment of peri-implantitis.

The present study opted for the sodium bicarbonate jet for decontamination because it is quite common in dental offices due to low cost, easy access, and handling by most professionals who prefer and choose to use it.

The results presented here show that, when applied for 60 seconds, the sodium bicarbonate jet significantly reduced the number of CFUs compared with the contaminated group ($P < .01$). However, it could not completely eliminate bacteria, as in the study by Batalha et al. Thinking of reducing the application time and obtaining the same effectiveness, the J30 group was included. However, when the application times of 30 and 60 seconds were compared, there was a statistically significant difference, with the best results in reducing the number of CFUs in the J60 group ($P < .01$), corroborating the results shown by previous studies, as performed by Nemer Vieira et al. and Batalha et al., both with an application time of 60 seconds.

In this sense, it seems logical to deduce that longer application times of the sodium bicarbonate jet may allow better results by reducing contamination. However, the clinical feasibility of this increase in application time remains a discussion, including the risks of developing
other problems, such as subcutaneous emphysema, which was already reported in the literature.\textsuperscript{15,22,23} According to the findings presented by a recent study,\textsuperscript{1} the particle size of the powder can also interfere with biofilm removal. According to the results presented by these authors, larger particles (40 to 60 µm), such as sodium bicarbonate, have a better surface cleaning capacity. In the present study, the sodium bicarbonate particles were approximately 125 µm, according to the manufacturer, and demonstrated good decontaminating potential compared with the contaminated control group. Even if the decontaminating potential of larger particles is better, disadvantages such as reaching more inaccessible areas due to surface roughness of the implant and less potential for powder solubility are described in the literature.\textsuperscript{1,24}

Another point to be discussed is: Would a longer application time be worse from the point of view of...
altering the implant surface, making its use less recommended due to potential effects on reosseointegration? The results of the qualitative descriptive analysis presented in this study suggest that after applying the sodium bicarbonate jet, there was no visible structural change in the studied augmentations for both application times. Damage, fractures, and changes on irregularities of the implants were not verified in SEM images.

Such results conflict with the findings of Matsubara et al., who performed an in vitro study and found that sodium bicarbonate particles, although effective in removing the biofilm, can cause changes to the implant surface. Such differences can be attributed to the evaluation method used. In the present study, only qualitative descriptive analysis was performed. In the study by Matsubara et al., the authors performed analyses of surface parameters in addition to SEM.

The literature shows that decontamination generally affects the surface of implants compared with the original surface. However, most decontaminating methods improve the biocompatibility of the titanium surface compared with untreated contaminated surfaces. In this sense, decontamination becomes an indispensable element in treating peri-implantitis, even though the original surface biocompatibility cannot be fully recovered.

The possibility of causing surface modifications is an important factor to consider when choosing the decontamination method, since surface characteristics can be very important for reosseointegration. Moharrami et al., in their systematic review, mentioned changes on the implant surfaces using the abrasive powder jet, mainly with sodium bicarbonate, but that these changes are not capable of significantly altering the surface morphology. Perhaps, for this reason, these changes were not seen in the present study. Besides, when evaluating the effectiveness of a decontamination method, it is important to consider that not all surface changes are harmful, and in most cases, the surface change is inevitable.

Considering the larger particle size used in this study, a significant reduction in the number of CFUs was expected, which in fact occurred; on the other hand, structural changes on the implant surface were not verified. In this sense, it is important to note that the results presented here come from an in vitro study with limitations and suggest further investigations. Quantitative analyses of the number of bacteria remaining on the surface and surface parameters are justifiable and indicated to help clarify and elucidate the issues surrounding this treatment protocol for peri-implantitis.

Limitations are also related to the angle and distance between the jet and implant surface that were not standardized in this study, once it varies according to the area being cleaned. In fact, numerous variables can influence the outcomes of this kind of study: air and water pressure of the device, distance between the nozzle and the implant surface, jet application time, mass, granulometry and hardness of the powder particle used, and type of implant surface tested. Also, the absence of an extra group using only the brushing method to decontaminate the implant surface to compare its effect alone is a limitation, although the test group decontamination methods were designed according to making it closer from a clinical protocol, since clinically, removal of the not-adhered biofilm before using special methods for implant surface decontamination is a common procedure.

CONCLUSIONS

Considering the limitations of an in vitro study, it is possible to conclude that the sodium bicarbonate jet effectively decontaminated titanium implants, causing no visible damage to the surface.

ACKNOWLEDGMENTS

The authors have no conflict of interest to declare.

REFERENCES