Plasma Sterilization in Oral Cavity

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Abstract: Nowadays, more and more people begin to pay attention to oral hygiene and health. Whether seeking medical treatment for oral diseases, oral cosmetic treatment or routine oral examinations, the public's demand for dental treatment is increasing, and oral treatment inevitably requires the use of dental diagnostic equipment. The plasma sterilization method has gradually won the favor of people due to its advantages of energy saving, environmental protection and high efficiency, and its sterilization effect has also been widely recognized in the medical industry. Therefore, a plasma sterilization equipment for oral treatment is designed in this paper. By analyzing the inactivation effect of the plasma equipment in treating oral bacteria, it is found that the plasma sterilization method can effectively remove oral bacteria. Sterilization with this equipment can prevent oral bacteria infect.

1 INTRODUCTION

The oral cavity is the gateway for microorganisms to enter the human body. There are many kinds of microorganisms and complex compositions in it. As one of the common diseases, oral diseases can occur in people of any age. Stomatology is also a high-risk department for nosocomial infection, and risk factors are ubiquitous, which deserves the attention of doctors and patients.

At present, many scholars have conducted in-depth research on the application of plasma sterilization in the oral cavity, and have achieved good results. For example, a drug administration recognized the wider utility of the plasma sterilization system and approved the use of the system in the sterilization of more medical and surgical instruments, indirectly promoting the plasma sterilization system, making it the only sterilization system in many health care facilities (Jain, 2021; Navneet, 2018). A scholar's research on the quality of disinfection and sterilization of dental clinics found that there are still many problems in dental clinic sterilization, such as failure to implement various management systems, pollution of the diagnosis and treatment environment, unreasonable layout of the diagnosis and treatment environment, disinfection of oral diagnosis and treatment instruments and materials (Nobuya, 2018; Kuwahara, 2018). Although there are many studies on the application of plasma sterilization in the oral cavity, further discussion is still needed on how to effectively extend the plasma equipment to the practical application of oral sterilization to solve the problem of oral infection.

This paper first introduces the concept of plasma, then explains some of its main parameters, then expounds the mechanism of plasma sterilization, then designs the overall structure of the plasma sterilization equipment, and finally analyzes the treatment of oral bacteria by the equipment. The sterilization effect proves the effectiveness of the plasma sterilization method.

2 AN OVERVIEW OF PLASMA AND ITS STERILIZATION MECHANISM

2.1 Main Parameters of Plasma

The main parameters of the plasma are:

(1) Plasma oscillation frequency

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$$s_p = \sqrt{\frac{e^2 n_e}{\theta_0 m_e}} \tag{1}$$

where n_e is the plasma free electron density; e and m_e are the electron charge and mass, respectively, and θ_0 is the dielectric constant in vacuum.

(2) Plasma collision frequency

$$F_{en} = 1.7\times10^{11}\frac{n_n}{2.7\times10^{19}}\sqrt{\frac{T}{300}} \tag{2}$$

$$F_{ei} = \frac{5.5 n_i}{T_e^{2/3}}\left[\ln\frac{280 T_e}{n_i^{1/3}} + \frac{1}{3}\ln\frac{T}{T_e}\right] \tag{3}$$

In a plasma, F_{en} is the electron-molecular collision frequency, F_{ei} is the electron-ion collision frequency, n_n and n_i are the densities of neutral particles and positively charged ions, respectively, and T and T_e are the ion temperature and electron temperature, respectively.

2.2 Mechanism of Plasma Sterilization

Matter can transform from its normal solid, liquid and gaseous states to a plasma state after absorbing enough energy (Filippova, Korepanov, 2020). For example, ice cubes absorb heat and turn into liquid water, water turns into gaseous water vapor when heated, and water vapor forms plasma when heated continuously (Filippova, Karpov, 2020; Antonini, 2019).

(1) The role of ultraviolet light: In the process of plasma formation, due to the transition of atoms, light of different wavelengths will be emitted, most of which are occupied by ultraviolet light. After ultraviolet rays are absorbed and sterilized by microorganisms, they can destroy or mutate their genetic material (Dogan, 2019; Kawasaki, 2018).

(2) Etching effect of high-energy particles: Using an electron microscope to observe the surface of sterile objects, it can be seen that after bacteria and viruses have been sterilized by plasma, their cellular structure has been severely damaged and covered with holes (Samoylova, 2019).

(3) Oxidation: NO produces an acid effect in the solution, causing the pH of the medium to drop sharply, killing the bacteria; OH will cause oxidation in the presence of water, which can cause the microbial membrane to perforate (Baldin, 2018; Laroussi, 2018).

3 PLASMA STERILIZATION EQUIPMENT DESIGN

3.1 Overall Structure Design of Equipment

As shown in Figure 1, the overall structure of the sterilization equipment mainly includes two modules, the decibel is the embedded control module and the power module.

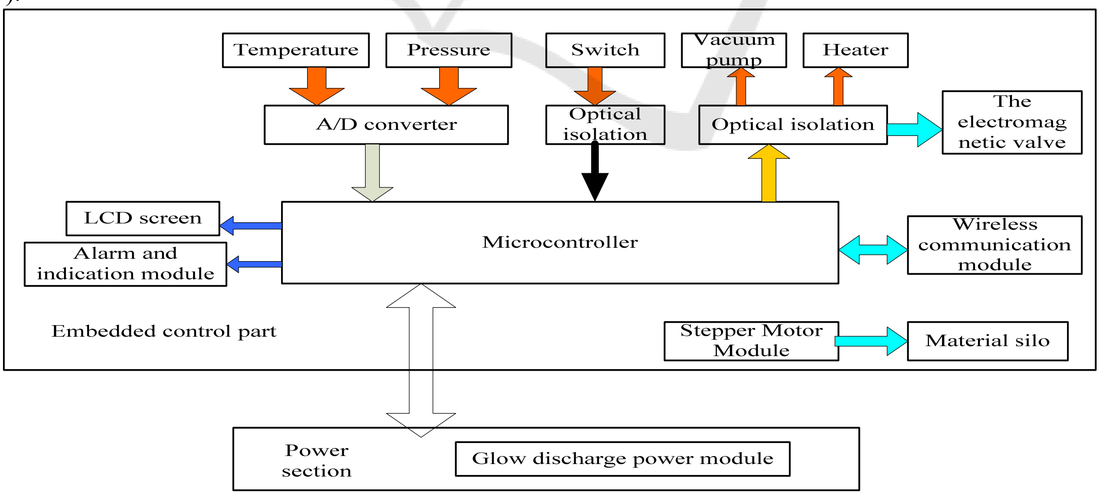

Figure 1: Overall structure of plasma sterilization equipment.

3.2 Design of Plasma Power Module

The voltage stabilizer converts the direct current into high frequency alternating current through the connection of the drive bridge converter, the alternating current is boosted by a high frequency transformer, and finally the high frequency and high voltage alternating current is sent to the sterilization output chamber to generate glow discharge plasma.

4 APPLICATION OF PLASMA STERILIZATION IN ORAL CAVITY

4.1 Sterilization and Disinfection Effect of Plasma Sterilization Equipment

The results are shown in Table 1. According to the data results, when the oral bacteria were not subjected to plasma sterilization, the number of colonies in the petri dish was 63, the average number of bacterial colonies after plasma sterilization for 1 s was 14, and the average number of colonies for 3 s was 6.677 pcs. Before 10s, the number of colonies decreased with the increase of treatment time, when the treatment time was 10s, the number of colonies was the least, and after 10s, the number of colonies increased with the increase of treatment time. That is to say, the number of colonies in the petri dish does not continuously decrease with time, but shows a trend of first decreasing and then increasing, but it will not exceed the number of untreated colonies, because the sterilization activity of the plasma is reduced.

Table 1: Comparison of sterilization effects.

Processing time	Average number of colonies (indivual)	Standard deviation
Not processed	63	8.269
1s	14	6.375
3s	6.677	4.082
5s	4.333	2.716
10s	1.211	0.327
15s	3.677	5.238
20s	5.832	11.558

4.2 The Effect of the Initial Density of Oral Cells on Plasma Sterilization

This experiment tests the effect of different oral initial bacterial densities on plasma sterilization. Oral bacteria were suspended in 1.5L deionized water, and the initial density of oral cells was set between 1*10^{4}cfu/mL and 3*10^{8}cfu/mL. The test results are shown in Figure 2. When the initial density of oral cells is 1*10^{4}cfu/mL, it takes 0.14s to sterilize 100 oral bacteria using plasma equipment, 1.68s to inactivate 1000 oral bacteria, and 10000 It takes 5.37s to inactivate 100,000 oral bacteria, and 8.42s to inactivate 100,000 oral bacteria. When 100 bacteria need to be inactivated, it takes 0.36s to inactivate oral bacteria with an initial density of 1.3*10^{5}cfu/mL, 1.45s for oral bacteria with an initial density of 2.4*10^{6}cfu/mL, and an initial density of 3*10^{8}cfu/mL oral bacteria inactivation takes 2.82s.

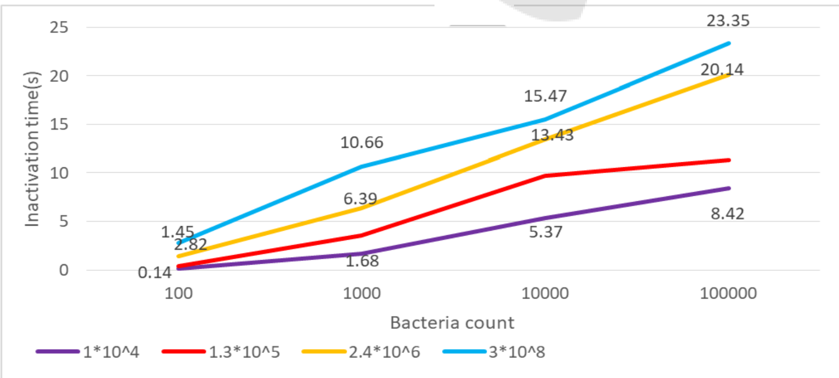

Figure 2: Bacterial inactivation time at different initial densities of oral cells.

5 CONCLUSION

In this paper, the application of plasma sterilization in inactivating oral bacteria was studied, and a plasma device was developed for secondary sterilization by gas glow discharge. In this paper, an experiment was carried out when the device was applied to oral sterilization. One was to compare the number of colonies in the petri dish without plasma equipment sterilization treatment and the treated petri dish. The second is to test the effect of the initial density of oral cells on the sterilization effect, which proves that when the initial density remains unchanged, the more bacteria that need to be inactivated, the longer the inactivation time; when the number of bacteria to be inactivated remains unchanged, the higher the initial density The bigger it is, the longer it takes to put out the fire.

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