Abstract

Nowadays plasma jets find versatile applications in industrial as well as medical fields. For example, they are used for surface activation in coating processes or in medicine for the decontamination of chronic wounds and for coagulation. The present paper presents the development of a plasma jet technology aimed at disinfecting microcavities such as those found in dentistry.

Background

Plasma is an ionized, quasi-neutral gas, in which electrons are partially or completely dissociated from the atoms or molecules. Accordingly, ions, electrons and neutral gas particles coexist in the plasma, also called the fourth state of matter. This state is achieved by supplying energy (thermal, electrical, etc.) to the gas. Figure 1 shows the transitions from the solid state to liquid, to gaseous and lastly, to the plasma state.

FIGURE 1
The four aggregate states. The supplied energy leads to an increased mobility of the elementary particles constituting the material, changing the way they bond to each other.
Plasmas are multicomponent systems that are highly reactive due to their high concentration of charged or excited (but neutral) particles. Each of the charged particles (positive and / or negative ions and electrons), excited atoms and molecules as well as photons (of different wavelengths) play a specific role in physical and / or chemical reactions with the materials with which the plasma is in contact.

A plasma can be generated under atmospheric pressure. If the gas, in which the plasma is generated, streams through a canal, the plasma forms a so-called “plasma jet” as it streams out of the nozzle.

Both plasma biology and plasma medicine are rapidly growing areas of application for atmospheric pressure plasma jets. So far, such plasmas have been mainly used in the field of sterilization of surfaces, of medical devices or for the surface treatment of implants to improve their biocompatibility [1]. The particles of the plasma interact with the cells of the microorganisms (see Fig. 2). They may contribute to sterilization by inactivating, killing or disintegrating the targeted microorganisms, e.g. bacteria or viruses [1]. More and more often atmospheric pressure plasma jets are used in medicine by direct application. In the field of wound healing for example, where the treatment of chronic wounds is carried out directly with a plasma jet, in various skin diseases, or even in new approaches such as cancer therapy [2].

**FIGURE 2**
Complex interactions between plasma and biological system [inspired from 3].
Technology

A plasma or plasma jet can be electrically excited from DC to microwaves. It can be pulsed at the same time and thus be operated with mixed frequencies. Frequency, voltage and current must be matched to the type of gas and gas flow so that the desired particles are generated, and these produce the desired effect with the desired target microorganism, but without causing side effects (for example excessive heating).

The company Freiburger Medizintechnik GmbH has designed and developed the plasma-jet based “AmbiJet” system from the ground up for use in dentistry (see Fig. 4). The Transient Spark Disinfection® is at the core of AmbiJet. The system (patent-pending) consists of a base unit (as a cart with foot switch or as a tabletop) with gas supply line and handpiece as well as a single-use mouthpiece with a flexible microneedle. The device is connected to a small gas cylinder. The design of the handpiece and of the mouthpiece are based on the ergonomics of contra-angle handpiece.

The specially developed electronics creates an extremely effective plasma in the microneedle. This plasma jet device does not only meet this basic requirement, but also ensures a high degree of safety for the patient and the operator. At each step of its development, the ISO standards for medical electrical equipment and various particular standards were taken into account.

FIGURE 3
LEFT: Picture of handpiece and mouthpiece. RIGHT: Picture of table-top version of AmbiJet.
Applications

The Transient Spark Disinfection® has a highly efficient, unspecific deactivating effect on bacteria as well as on virulent components, antigenic bacterial residues and cell residues.

For periimplantitis treatment, the Transient Spark Disinfection® is used to disinfect the implant. A mouthpiece is then used to deposit carbon-based, functionalized compounds on the implant surface. This reduces its nano-roughness and tailors its surface properties to minimize the adhesion of bacteria. This treatment step is to prevent reinfections.

For periodontitis treatment, the Transient Spark Disinfection® is applied using a flexible foil micronozzle, which the operator shifts between the inflamed gingiva and the tooth without having to proceed surgically. The special form of DFR (Dry Film Resist) technology developed by the founders is currently the only way to create a plasma jet in a flat and flexible nozzle in the sub-millimeter range.

A flexible microneedle with an outer diameter of 300 μm is ideal for the endodontics purpose as the reactive species are brought deep into the apical region of the root canal. As opposed to liquids, the plasma is not subject to surface tension and can therefore penetrate into recessions and through dentin tubules.

FIGURE 4
Application of AmbiJet in endodontics (LEFT) and peri-implantitis (RIGHT) therapies.
Unique advantages of the TSD®

- One platform technology for three indications
- A significantly higher and broader effectiveness at disinfecting, including dental and implant microcavities.
- Very first method to control reinfection
- Increased treatment safety by eliminating the use of potentially antibiotics and allergenic substances (e.g. sodium hypochlorite, CHX).
- Increased safety by avoiding rinsing accidents and emphysema.
- Renunciation of pharmacological active substances

References

