International Journal of Dental Sciences
www.dentaljournal.in
E-ISSN: 2663-4708, P-ISSN: 2663-4694
Received Date: 03-11-2018 Accepted Date: 04-12-2018; Published: 04-01-2019
Volume 1; Issue 1; 2019; Page No. 14-17

Cold atmospheric plasma in dentistry: The crowning glory

Anjali Jayaraj[1], Jayakrishnan[2], Satish SV[3], Krishna Prasad Shetty[4], K Nillan Shetty[5], Rohan Rai[6], Govind SL[7], Navya LV[8]
[1, 3] Department of Conservative Dentistry and Endodontics, Navodaya Dental College, Raichur, Karnataka, India
[2, 5, 6] Department of Orthodontics and Dentofacial Orthopedics, A.J Institute of Dental Sciences, Mangalore, Karnataka, India
[4] Department of Restorative Dentistry, Ajman University, Ajman, United Arab Emirates
[7] Department of Conservative Dentistry and Endodontics, Vinayaka Missions Sankarachariyar Dental College, Salem, Tamil Nadu, India
[8] Department of Periodontology, Vinayaka Missions Sankarachariyar Dental College, Salem, Tamil Nadu, Kerala, India

Abstract
The three states of matter that exists are solid liquid and gaseous state. Apart from these three stages yet another category of matter is called as plasma. The universe is mostly made up of plasma and exists as the highest quantity of matter. Plasma is a natural phenomenon and can be seen in the polar areas in the form of Aurora borealis, northern lights and can be artificially created. A variant of plasma called the non-thermal plasma or cold atmospheric plasma is readily used in the field of biomedicine these days. The temperature of application is less than 104°F. Cold Atmospheric Plasma can be used in the field of dentistry and has a wide horizon of applications.

Keywords: cold atmospheric plasma, dielectric barrier discharge, plasma pencil

Introduction

Plasma is the fourth state of matter other than solid, liquid and the gaseous state. Plasma is a collection of gaseous molecules which are in an ionized stage [1]. A continuous source of heat energy is supplied to the gaseous molecules which get ionized to form highly charged particles and constitute to form plasma. The heat energy also causes the dissociation of the molecular bonds. Plasma has both a combination of positively charged ions, negatively charged ions along with radicals, neutral particles [2]. The electrons once stripped off from the atoms leads to the formation of ionized particles and form the stage of plasma. Plasma particles does not have a particular shape like the gaseous molecules but is affected by the magnetic and electric field [3].

Plasmas are naturally energetic because stripping electrons uses constant energy. Naturally occurring plasma forms are mainly fire, northern lights seen in the polar areas, nuclear fusion reactions of the sun. Artificially plasma can be created in plasma screen, plasma lights etc. Depending on the temperatures, plasma can be divided mainly to thermal and non-thermal plasma. Thermal plasma has electrons and heavy particles (neutral and ions) at the same temperature, thereby is in a state of thermal equilibrium with each other [4].

Cold Atmospheric Plasma (CAP) is also called the non-thermal because it has electron at a hotter temperature than the heavy particles that are at room temperature. CAP is a specific type of plasma that is less than 104°F at the point of application. There by cold atmospheric plasma can be used as a treatment modality in living organisms [4].

The state of plasma was first identified by the British physicist Sir William Crookes in the year 1879. Later on, in year 1929 Irving Langmuir coined the term plasma. Very little studies were conducted in the field of plasma and its properties; however, plasma was used to generate ozone which was employed to remove contaminants and toxins from water. Scientists made efforts to explore the wide horizon of application and properties of plasma by the mid-1990. By 1997 scientists from various fields underwent more re searchers and studies on the relationship between plasma and biological molecules. Various studies were conducted to prove that plasma can be used as a decontaminant or sterilizing agent. In the present era plasma research has evolved at a rapid rate and is playing a major role in the area of biomedical, aerospace, military, environmental and agriculture.

Plasmas can be produced by various means, e.g. radio frequency, microwave frequencies, high voltage ac or dc, etc. The main body of the device is made of a medical syringe and a needle. They are used for guiding the gas flow. The needle also serves as the electrode, which is connected to a high-voltage (HV) sub microsecond pulsed direct-current (DC) power supply (amplitudes of upto 10 kV, repetition rate of upto 10 kHz, and pulse width variable from 200 ns to DC) through a 60-kΩ ballast resistor R and a 50-pF capacitor C, where both the resistor and the capacitor are used for controlling the discharge current and the voltage on the needle. Because of the series-connected capacitor and the resistor, the discharge current is limited to a safety range for a human. It is found that, if the resistance of R is too small or the capacitance of C is too large, there is feeling of weak electric shock when the plasma is touched by a human.

The diameter of the syringe is about 6mm, and the diameter of the syringe nozzle is about 0.7mm. The needle has an inner

diameter of about 200µm and a length of 3cm. Working gas such as He, Ar, or their mixtures with O2 can be used. The gas flow rate is controlled by a mass-flow controller. [2] When working gas such as He/O2 (20%) is injected into the hollow barrel of the syringe with a flow rate of 0.4 L/min and the HV pulsed dc voltage is applied to the needle, homogeneous plasma is generated in front of the needle. finger can directly contact with the plasma or even with the needle without any feeling of warmth or electric shock. Therefore, this device is safe for the application of root-canal disinfection.

The various methods and carriers for delivering the cold atmospheric plasma are Dielectric Barrier Discharge (DBD) (Fig.1), Atmospheric Pressure Plasma Jet (APPJ) (Fig 2), Plasma Needle, and Plasma Pencil (Fig 3).

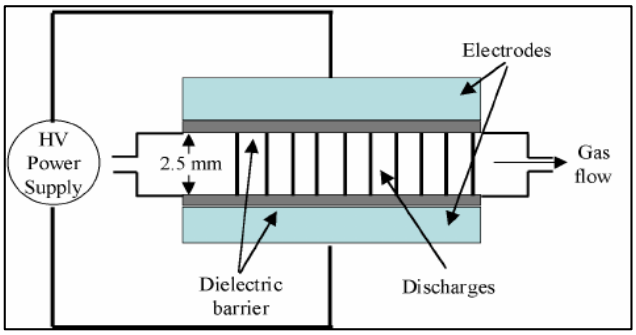

Fig 1: Dielectric Barrier Discharge

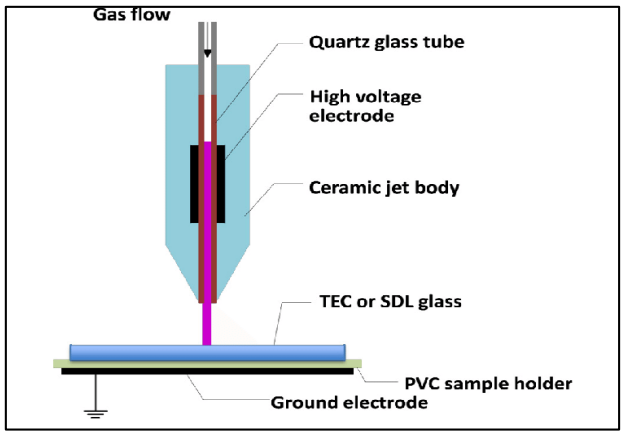

Fig 2: Atmospheric Pressure Plasma Jet

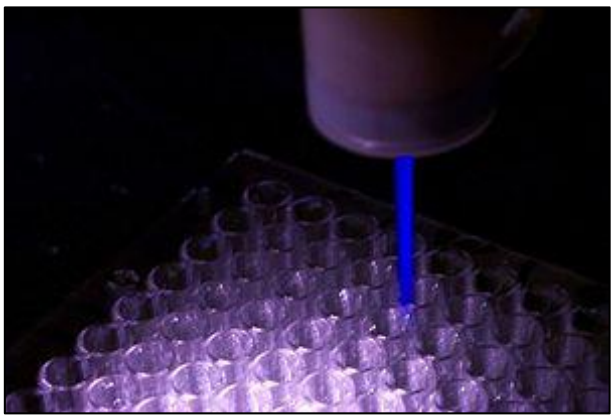

Fig 3: Plasma Pencil

2. Applications of cold atmospheric plasma in dentistry

2.1 Sterilisation

Various researches and studies have proven that plasma has a high sterilization capacity and to kill bacteria at a higher rate. The bacterial cell membrane is composed of a filliped layer which is made up of unsaturated fatty acids and proteins. Plasma source generate free radicals which attack the hydroxyl group of fatty acids and there by cause a disruption of bacterial cell wall. This leads to the bacterial death. Rupf *et al* demonstrated the se of plasma jets to sterilize the dental surfaces. Plasma acts around the surrounding areas along with the area to be sterilized. Whittaker *et al*. has indicated that the use of gas plasma cleaning may be extremely beneficial in reducing the absolute amount of proteinaceous materials that may be transferred between patients when endodontic files are reused [5].

Su-Jin Sung *et al*. developed a dental sterilizer which can sterilize most materials, such as metals, rubbers, and plastics using cold plasma [6]. Sladek *et al*., studied the interactions of the plasma with dental tissue using a plasma needle. It is an efficient source of various radicals, which are capable of bacterial decontamination; but it operates at room temperature and thus, does not cause bulk destruction of the tissue [7]. Raymond EJ *et al*., studied the interactions of the plasma with dental tissue using a plasma needle.

2.2 Dental Caries

Plasma source employs an invasive method to remove the caries from the irregular surface of the tooth. Activated plasma species can penetrate through the dentine and thereby leads to elimination of bacteria [3]. E coli is the main pathogen seen in dental caries and the plasma needles are used as the carrier agent to deliver plasma to the area of interest. It was Eva Stoffels who pioneered this approach. Goree *et al* advocated the use of plasma to target streptococcus variants seen on the tooth. Yang *et al* introduced a low temperature argon plasma to kill lactobacillus and streptococcus.

2.3 Biofilms

Biofilms are the syntrophic consortium of microorganism which is adhered to a surface. Cold atmospheric plasma can target the pathogens in the biofilms [2]. An invitro study conducted by Koban *et al* proved that cold plasma had a greater efficiency of eradicating the pathogens than chlorhexidine.[8] Zhang *et al.* presented a paper on treatment of streptococcus mutans bacteria by a plasma needle in which a dielectric barrier discharge plasma needle was used at atmospheric pressure with a funnel shaped nozzle. The preliminary characteristics of the plasma plume and its applications in the inactivation of Streptococcus mutans (S. mutans), the most important

Microorganism causing dental caries, were presented in this paper.

2.4 Oral Candidiasis

Various conditions like candida associated denture stomatitis, gingival erythema, median rhomboid glossitis, angular stomatitis are various lesions associated with candida. Koban *et al* ad Yamazaki etal n their various researches proved that cold plasma

has a high sterilization efficacy towards candida albicans. [9] They mainly advocated the use of plasma jets against the candida associated lesions.

2.5 Root Canal Sterilisation

The state plasma can be touched by bare hands. The point of application of plasma is 104 °F. [2] This property of plasma is employed for the root canal disinfection. A mixture of helium and oxygen is introduced into the root canal as the working gas and is activated. Here it mainly targets the e coli which is primary causative factor for the re infection and retreatment cases. [10] Pan J etal advocated various studies to evaluate the efficacy of plasma in the root canal disinfection.

2.6 Composite Restoration

Composite is widely used in the restorative dentistry. Composite restoration involves a process called etching which helps in the penetration of adhesives more into the dentinal layer. Sometimes this protein layer causes a disruption of the restoration due to inadequate bond strength.

Various studies have proved that plasma treatment on a composite restoration has increased the bond strength [2] by about 60%. Wang etal employed plasma brush to deliver the plasma source at the tooth resin interface.

2.7 Bleaching

Plasma has the property of production of hydroxyl ions on activation along with disruption of protein molecules present on the living tissue. Lee etal advocated the use of cold plasma in tooth bleaching in presence of light source. Park etal used hydrogen peroxide along with plasma with a very low frequency. Plasma jets were used in the delivery of plasma to the target areas [11, 12].

2.8 Post and core

Yavrich *et al*, studied the effects of plasma treatment on the shear bond strength between fiber reinforced composite posts and resin composite for core build- up and concluded that plasma treatment appeared to increase the tensile-shear bond strength between post and composite.

2.9 Surface reconditioning

An increased osseointegration of bone to implant contact is seen in plasma treated titanium implants. Plasma treatment of implant increases the interaction between connective tissue, bone and the implant surface. Researches demonstrate and increase in the number of osteoblast formation in case of plasma treatment.

2.10 Oncology

It has been demonstrated that Cold Atmospheric Plasma induces apoptosis, necrosis, cell detachment, and deterioration of tumour cells by disrupting the S phase of cell division. Thus, there are many potentials of treatment in oncology. [4] Promising findings obtained from in vivo and in vitro studies of CAP in oncology show that CAP will find its niche in the treatment of cancer patients in the future. However, more studies need to be performed regarding its technique and implementation.

3. Conclusion

Cold atmospheric plasma has a bright future in dentistry due to its antibacterial properties and better compatibility with dentinal tissues. Plasma treatments are basically painless, noiseless, invasive, patient friendly. The technique is sensitive to use and expensive. The flame is cool to touch without any feeling of warmth or touch. [2] It operates at room temperature and does not cause bulk destruction of the tissue, being superior to lasers. It does not work well in cases where amalgam restoration is present in the oral cavity. Cost of the equipment, marketing, maintenance and availability are also some of the issues at present. Plasma needle technology has a long way to go and shall prove its applicability in the days to come. Plasma can be used in almost all the branches of dentistry. However, more studies need to be performed regarding the mechanism of action.

4. References

1. Arora V, Nikhil V, Suri NK, Arora P. Cold Atmospheric Plasma (CAP) in Dentistry. Dentistry, 2014. 4:189.
2. Nair RS, Babu B, Mustaq E. Cold atmospheric plasma in dentistry. J Oper Dent Endod. 2016;1(2):82-86
3. Smitha T, Chaitanya Babu N. Plasma in Dentistry: An update. IJDA. 2010; 2:210-14.
4. Somya Govil, Vishesh Gupta, Shobhit Pradhan. Plasma needle: The future of Dentistry. Indian Journal of Basic & Applied Medical Research. 2012; 2:143-7.
5. Whittaker AG, Graham EM, Baxter RL, Jones AC, Richardson PR, *et al*. Plasma cleaning of dental instruments. J Hosp Infect. 2004; 56:37-41.
6. Sung SJ, Huh JB, Yun MJ, Myung B, Chang W, *et al.* Sterilization effect of atmospheric pressure non-thermal air plasma on dental instruments. J Adv Prosthodont. 2013; 5:2-8.
7. Sladek REJ, Stoffels E, Walraven R, Tiebeek PJA, Koolhoven RA. Plasma treatment of dental cavities. IEEE Trans Plasma Sci. 2004; 32:1540-3.
8. Koban I, Matthes R, Hubner NO, Welk A, Meisel P, *et al*. Treatment of Candida albicans biofilms with low-temperature plasma induced by dielectric barrier discharge

and atmospheric pressure plasma jet. New J Phys. 2010; 12:073-039.
9. Yamazaki H, Ohshima T, Tsubota Y, Yamaguchi H, Jayawardena JA, *et al*. Microbicidal activities of low frequency atmospheric pressure plasma jets on oral pathogens. Dent Mater J. 2011; 30:384-391.
10. Pan J, Sun K, Liang Y, Sun P, Yang X, Wang J, Zahng J, Zhu W, Fang J, Becer K J. *et al* Cold Plasma Therapy of a Tooth Root Canal Infected with Enterococcus faecalis Biofilms in Vitro J Endod. 2013; 39:105-110.
11. Lee HW, Kim GJ, Kim JM, Park JK, Lee JK, Kim GC. Tooth bleaching with no thermal atmospheric pressure plasma. J Endod. 2009; 35:587-91.
12. Jamali A, Evans PD. Plasma treatment and bleaching to remove blue stain from lodge pole pine sapwood. Eur J Wood Prod. 2013; 71:675-77.