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# Plasma therapy in dentistry

[1]Deepak Narang, Reader, Department of Oral Medicine and Radiology, Deshbhagat Dental College, Punjab, India.

[2]Tejveer Singh, Professor, Department of Oral Surgery, Deshbhagat Dental College, Punjab, India.

**Corresponding Author:** Deepak Narang, Reader, Department of Oral Medicine and Radiology, Deshbhagat Dental College, Punjab, India.

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## Abstract

Plasma is known as 'fourth state of matter'. Plasma is two types: thermal and non-thermal or cold atmospheric plasma. Electrons and heavy particles (neutral and ions) present at the same temperature in Thermal plasma. Cold Atmospheric Plasma (CAP) is said to be non-thermal because it has electron at a hotter temperature than the heavy particles that are at room temperature.

Non-thermal or cold plasmas are partially ionized gases whose electron temperatures usually exceed several tens of thousands degrees K, while the ions and neutrals have much lower temperatures. Due to the presence of reactive species at low temperature, the biological effects of non-thermal plasmas have been studied for application in the medical area with promising results

This review demonstrates different application of plasma in dentistry like effect of plasma on dental implant, dental cavity decontamination, sterilization, root canal disinfection, tooth whitening, polymerization etc.

**Keywords**: Thermal plasma, non-thermal plasma, Cold atmospheric Plasma, Dentistry

## Introduction

Plasma, by far the most dominant state of matter in the universe, was identified by Sir Crooke in 1879, and was first named "plasma" by Langmuir in 1929. After a long dormant phase since Simens used firstly plasma discharge in order to create ozone in the late 1850s, plasma research has recently evolved at a rapid pace and extended into biomedical, environmental, aerospace, agriculture and military fields[1-3].

As in medicine, the dental applications of physical plasma can be mainly subdivided into two principal approaches:

One is the use of plasma technology for the treatment of surfaces, materials or devices to realize specific qualities for subsequent special applications including disinfection, and the other is the direct plasma application on or in the human body for therapeutic purposes; however, clear-cut classifications are sometimes impossible because of overlaps.

In addition, the use of plasma for medical purposes could be divided according to its temperature and the air pressure at which it is generated[4].

Normally, the electron and ion densities in plasmas are approximately equal (a condition called quasi-neutrality), but the respective electron and ion temperatures can be quite different. Plasmas are usually classified as thermal and non-thermal plasmas[5].

Thermal plasmas are in thermal equilibrium, which means that their temperatures are relatively homogenous throughout the heavy particles (i.e., atoms, molecules, and ions) and electrons that usually span in the range of thousands of K. The so-called non-thermal or cold plasmas are partially ionized gases and their electron temperatures exceed several tens of thousands K, while the heavy particles (ions and neutrals) have a much lower temperature[5].

Plasma can be also generated under different pressure conditions, including atmospheric pressure. In the last decade, atmospheric pressure plasmas have become a very attractive tool for material processing applications because they are generated in an open environment and can be easily implemented in online processing. However, working at atmospheric pressure has some disadvantages[6].

This review aims at demonstrating different application of plasma in dentistry like effect of plasma on dental implant, dental cavity decontamination, sterilization, root canal disinfection, tooth whitening, polymerization etc.

**Plasma therapy in dentistry**

| Surface Treatment | Direct Applications |
|---|---|
| Modification of the implant surfaces | Microbicidal activities |
| Enhancing adhesive qualities | Decontamination Root canal disinfection |
| Surface coating | Tooth Bleaching |
| Plasma cleaning | Miscellaneous |

**Surface treatment**

**Plasma therapy in dental implantology**

Restorative treatment using dental implants has become a standard procedure in contemporary dentistry. Since the implant surface is the first part to interact with the host, it has been thoroughly investigated in an attempt to hasten the early host-to-implant response[7-9].

Numerous possibilities have been suggested and evaluated for this purpose[10-12]; however, there is no consensus concerning which kinds of surface roughness and/or chemistry combination will result in optimum osseointegration[13-15].

Among these properties, implant surface hydrophilicity or wettability has recently received considerable attention.[16-18].

Recent study, stated that plasma treatment reduced the contact angle and supported the spread of osteoblastic cells. One of the advantages of plasma treatment is that it leaves no residues after treatment.[19-21].

Several studies reported the plasma treatment of zirconia implants, which is increasing as an alternative to the conventional titanium implant due to its superior esthetic properties. They also demostrated the increase in hydrophilicity and enhanced osseointegration in in vitro as well as in vivo experiments[21-23].

**plasma therapy in dental composite restoration**

As a critical factor in improving the performance of dental composites, adhesive dentistry has greatly advanced since being first discovered by Buonocore[24]. For most dental joints, one set of adherends is usually composed of any dental substrates or previous restorations while the other set consists of restorative ones such as composite, amalgam, or ceramics[25].

Conventional adhesive systems employed several methods to improve wettability, to elevate the surface energy and to increase the roughness through techniques involving etch-and-rinse, acid primers, Hydroxyethyl methacrylate (HEMA) primers and laser irradiation[26-29].

In the same respect, plasma treatment has been introduced as an alternative or additional procedure, especially in the bonding of ceramic restorations, which is more difficult to achieve. As an alternative for adhesion enhancement in dental ceramic bonding, atmospheric pressure plasma treatment has been suggested. It enhances adhesion by producing carboxyl groups on the ceramic surface and improves the surface hydrophilicity as a result[30,31,32,]

Another attempt using plasma fluorination was reported, which is expected to increase hydroxylation at the surface, making it more reactive, thus allowing for covalent bonding between the zirconia surface and resin cement[33-37]

**Plasma therapy in sterilization**

In contrast to the conventional methods of cleaning such as the use of solvents or aggressive chemicals, plasma cleaning leaves no residue, and, when optimized, typically generates only CO2, H2O, and N2 as gaseous waste. Gas plasma treatment has the potential advantages of lack of toxic residue effects, reduced turnover time, and applicability for sterilization of heat- and moisture sensitive instruments[38,39].

Dental treatment can frequently induce cross-contamination between dental patients and dentists through instruments and materials as well as between impression materials and dental technicians[40-42].

Contaminated endodontic files exposed for a short period to low-pressure oxygen–argon plasma showed a reduction in the absolute amount of proteinaceous materials in a preliminary study, but the exact duration was not described unfortunately[43,44].

**Direct treatment**

**Plasma therapy in microbial activities**

Methods for the decontamination and conditioning of intraoral surfaces are of great interest in the field of dentistry. Cold plasmas are of particular interest, as heat damage to dental pulp must be prevented.

| Sn | Group | Species |
|---|---|---|
| 1 | Streptococci | Streptococcus mutans, Streptococcus sobrinus, Streptococcus parasang is, Streptococcus mitis, Streptococcus Oralis, |
| 2 | Lactobacillus | Lactobacillus fermentum, Lactobacillus plantarum, Lactobacillus acidophilus, |
| 3 | Actinomyces | Actinomyces Israeli, Actino my cesgerencseriae, Actino my cesnaeslundii, |
| 4 | Microaerophi les | Actinobacillusactinomycetemcomitans, Eikenellacorrodens |
| 5 | Aerobes | Neisseria mucosa, Haemophilusparainfluenza |
| 6 | Anaerobes 1 | Fusobacterium nucleatumssnucleatum, Campylobacter rectus, Veillonellaparvula, Corynebacterium matruchotii, Prevotellanigrescens/intermedia |
| 7 | Anaerobes 2 | Porphyromonasgingivalis, Selenomonasnoxia, Micromonas micros |

**Bacteria that can be inactivated by plasmas include[45,46]**

**Plasma therapy in periodontology**

Periodontal disease (PD) affects the dental support tissues and it is a major cause of tooth loss impacting on individual's function and social behaviour. Among the bacteria involved in periodontitis development, Porphyromonas gingival is, Tannerella forsythia and

Treponema denticola, known as red complex, are the most studied and associated to tissue destruction. Due to the limited gain of the traditional periodontal treatment, it is necessary to find new adjuvant therapies.

Kncuk et al, in the first clinical trial using plasma therapy as an adjuvant therapy for non-surgical treatment in one-time application protocol, found significant gain of clinical attachment length after three months. They also observed the elimination of microorganisms in the red complex and recolonization reduction[47].

**plasma therapy in cariology**

Plasma can decontaminate dental cavity without drilling. It is very useful to treat child patients. Eva Stoffel's, suggested the use of plasma needle on the basis of the ability of plasma to kill E. coli[48].

Goree et al. reported that non-atmospheric plasma can kill S. mutans. Plasma causes bacterial decontamination in room temperature with the help of free radicals. Plasma does not cause bulk tissue destruction. Laser or mechanical technique also decontaminate dental cavity but they produce heat and cause healthy tissue destruction[49].

**Plasma therapy in oral oncology**

The incidence and prevalence of oral cancer have been continuously increasing in numbers, as well as the mortality rates, especially among younger patients. Oral cancer stands as an international public health problem and one of most common cancer with more than 177,000 deaths and 354,500 new cases year worldwide[50].

In addition to surgical approaches, the stereotactic body radiotherapy associated with smart drug delivery systems (SDDSs) have been proposed to oral cancer therapy. The immunotherapy also advanced considerably in the last years[51].

However, those new discoveries involve expensive treatments and ultra-expensive drugs. For this reason, the search for alternative is needed. The potential of plasma in oral oncotherapy is based on its selectivity towards malignant cells, capacity to induce cell death, immune response, and controlled discharge of RONS that can interfere on the molecular mechanisms of the disease[52].

Plasma treatment as a tool to control oral cancer cells has been studied in the last years. Han et al. reported that plasma induced DNA damage in SCC-25 oral cancer cells. The effect on head and neck squamous cell carcinoma (HNSCC) was also detected[53,54].

Plasma can also be an alternative for the treatment of oral lichen planus, a precancerous lesion. Interestingly, cancer cells such as SCC-15 and HNSCC were more sensitive to plasma when compared to non-cancer cells lines[55].

**Plasma therapy in endodontics**

Lu et al. used a plasma jet device which could generate plasma inside root canal. Plasma causes disinfection of the canal without feeling pain. The root canal system has complicated structures like, isthmus, deltas, ramifications, particular dentinal tubules and irregularities[56].

It has been suggested that bacteria can enter dentinal tubules as deep as 500-1000 μm. When Helium/oxygen (20%) is used as plasma, vibrational and rotational temperatures of the plasma are about 2700 K, 300 K respectively and current is about 10 mA then effective destruction of E. faecalis is found. Ying long et al performed an in-vitro study and found that twelve minutes exposure of non-thermal plasma for three weeks completely kill E. Faecalis[57].

**Plasma therapy in oral candidiasis**

Oral candidiasis is an opportunistic disease with high prevalence among immune compromised patients. Lately, reports on refractory cases of oropharyngeal candidiasis are increasing and the treatment of these cases has faced considerable challenges due to the increasing occurrence of antifungal resistance and low number of new antifungal molecules[58].

Anti-Candida albicans effect was reported by some studies. Additionally, Plasma showed modulatory effects on C. albicans virulence factors, such as adhesion and filamentation. Suppression of ergosterol biosynthesis has been observed[59,60]

**Future perspective**

Plasma therapy has a great potential to be used in dentistry in the near future, with applications in several dental specialties. plasma might contribute to the treatment of refractory infectious diseases and control of oral cancers.

Currently, the major challenge to be overcome is the determination of standardized therapeutic protocols to each disease that can be validated by controlled clinical trials[60].

**Limitations and conclusion**

The study of plasma integrates various fields of science, such as physics, chemistry, biology, and engineering, and has recently involved medicine and dentistry in its research efforts. However, dentists do not realize well even though they use plasma in daily practice, such as electrosurgical applications for tissue removal, cauterization, and plasma spraying of titanium implants.

Due to new technology, plasma technology also has some limitations like, cost of the equipment, marketing, maintenance and availability. Now-a-days, research of the plasma therapy effect on tumor cells is being done and some positive results are reported. The effect on normal cells has to be studied in depth and validation needed for its successful application. Some more research is needed for this technology to be used in a cost effective, efficient and predictable manner in clinical settings.

Clear conclusions are not yet drawn about the effects of plasma therapy on human and non-human cells. Further exploration should be required. The confusion may be due to the beginning era of the novel field of plasma dentistry.

More in vivo studies strongly need for the plasma treatment to be used and accepted widely. The user-friendly technique would gain more popularity because manufacturers recently provide hand-held devices proper for the clinic. Further understanding of the cellular and molecular mechanisms involved could also give researchers and clinicians insight into future applications

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