

Dental Applications of Cold Atmospheric Plasma

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ABSTRACT

Matter is mostly thought to exist in liquid, solid, and gaseous state. Apart from these three there is another category of matter called as plasma. Out of all the states of matter, plasma is found to exist in the highest quantity, that is what the stars and galaxies are made up of. Plasma could also become a new way to prepare cavities without causing pain. It is capable of inactivating bacteria and it is not inflammatory to the tissues, which makes it a helpful tool in removing dental caries and treating them.

Keywords: Cold Atmospheric Plasma (CAP), Dental caries, Plasma, Sterilization, Tooth Bleaching

INTRODUCTION

Plasma is the fourth state of matter, discovered by the British physicist Sir William Crookes in the year 1879, but the name “plasma” was applied by Irving Langmuir, an American chemist, in 1929.

Particles whose electrons are taken away from their atoms can become a state of plasma. A continuous flow of energy is needed to tear off electrons from their atoms. If the energy is lost, then the electrons can reattach and the plasma gets converted to gas once again.

The most peculiar fact about plasma is that it can exist in a varying range of temperatures without changing its state. For Example the aurora borealis, or northern lights, is as cold as ice, while on the other hand the core of a distant star is white hot.

Apart from these, other widely known examples of plasmas include neon signs, lightning, and fluorescent lights.¹

Plasma particles does not have any particular shape and resembles gas without a container. But plasma differs from gases, due to its property of being controlled by magnetic and electric fields, which can turn its shapeless form into useful shaped structures.¹

Plasmas can be classified as “thermal” or “non-thermal” according to the relative temperature of Ions, Neutrons and electrons.

The heavy particles and the electrons are at equal temperature in case of “Thermal plasma”, i.e., they are in thermal state of balance with one another.

Whereas Non-thermal plasmas have electrons, which are much “hotter” than the ions and neutrons, which are at a much lower temperature. Atmospheric plasma is considered cold when it is 40 °C or less. Thus such Cold Atmospheric Plasma can be used as an treatment alternative in living beings.² Gases that can be used to produce CAP are Helium, Argon, Nitrogen, Heliox (a mix of helium and oxygen), and air.³

METHODS OF PRODUCTION

For the production of plasma, a maintained flow of energy is required. The discharge needed to produce CAP can be induced electrically or through light energy or even through thermal energy. Various different types of CAP have already been

developed for biomedical uses. Some methods used to produce CAP include:

- Dielectric Barrier Discharge (DBD),
- Atmospheric Pressure Plasma Jet (APPJ)
- Atmospheric Pressure Plasma Brush (APPB)
- Plasma Needle
- Plasma Pencil.

APPLICATIONS OF CAP IN DENTISTRY

Cold atmospheric plasma has many uses in dentistry which includes: Removal of dental caries and tooth preparation to receive restorative materials, sterilization of endodontic files and other surgical instruments, elimination of persistent and non-accessible biofilms, a thorough root canal disinfection, tooth surface preparation so as to increase bond strength of composite and bleaching etc. (Figure - 1). Due to its ability to deactivate microorganisms, cause cell detachment, and cause death in cancer cells, researchers have been interested in finding uses for CAP in oncology.³

Sterilization

There is limited use in sterilization of surgical instruments with the application of cold atmospheric plasma. Whittaker et al. in his study has suggested that cleaning with gas plasma may be exceptionally advantageous in decreasing the cross contamination between patients during endodontic treatments.⁴

Surface conditioning

Plasma treated titanium implants showed enhanced osseointegration of bone-to-implant contact, which improved the interaction between connective tissue and the bone itself.⁵ Similar research demonstrated that the application of plasma actually altered dentin surface chemistry, which improved osteoblast spreading.⁶

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.³ 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.

Dental caries

Cold atmospheric plasma jets were used against dental caries causing micro-organisms by Rupf et al. from Homburg,

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Figure-1: Applications of CAP in dentistry.

Germay.⁷ Non-thermal atmospheric plasma jets could be used for the disinfection of dental surfaces.

Tooth Bleaching

CAP can also be used to bleach teeth. Lee et al. showed that atmospheric pressure plasma in place of light sources bleached teeth by increasing the production of OH radicals and it also eradicates the surface proteins.⁸ In addition to this plasma also helps in removing stains caused by coffee or wine, when it is combined with hydrogen peroxide, this was shown in a study by Lee et al. on extracted teeth.⁸

Composite

Use of plasma in composite restorations Preliminary data has also shown that plasma treatment increases bonding strength at the dentin/ composite interface by roughly 60 percent, and with that interface-bonding enhancement to significantly improve composite performance, durability, and longevity. Dr. Wang and his colleagues investigated the atmospheric cold plasma brush (ACPB) treatment effects on dental composite restoration for improved interface properties and their experimental results showed that atmospheric cold plasma treatment can modify the dentin surface and thus increase the dentin/adhesive interfacial attachment.⁹

Disinfection during endodontic treatment

Disinfection of infected tissue in a dental cavity or during an endodontic treatment can be done using lasers or mechanical techniques. But both these techniques can cause destruction of healthy tissue due to overheating. Raymond E. J. et al. in his study used a plasma needle to observe the interactions between plasma and dental tissues.¹⁰ A plasma needle is an effective source of free radicals, and they have the property of eradicating microbial disinfection without causing destruction of the tissue. He concluded, from his research that “plasma treatment is a novel tissue-saving technique, which allows cleaning of irregular and narrow channels”.¹⁰

Lu et al in his study used a dependable and easy to use plasma-

jet apparatus, which could direct plasma in the root canals. This plasma could be directed manually into the root canal for decontamination without any pain.¹¹

CONCLUSION

CAP has a bright future in dentistry and oncology due to its antimicrobial and cell necrosis properties. Particularly in dentistry, studies in CAP have shown promising findings in improving bleaching, removal of biofilms, sterilization of surgical instruments, in composite restoration. Studies also show that there are positive findings obtained from in vivo and in vitro studies of CAP in oncology, thus CAP will find new potentials in the treatment of cancer patients in the future. However, more studies need to be performed in the direction of ease of usage of CAP and increasing its field of application.

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