REVIEW ARTICLE

Hyperbaric Oxygen Therapy: Mechanism of Action and its Application in Periodontics: A Review

Harshita Gupta

Abstract

Hyperbaric oxygen (HBO) therapy is widely used in a number of areas of medical practice. HBO increases local oxygen distribution, especially at the base of the periodontal pocket, which inhibits the growth of anaerobic bacteria and allows the ischemic tissues to receive an adequate intake of oxygen sufficient for a rapid recovery of cell metabolism, which may help to treat many periodontal diseases and also may act as a stimulator of osseointegration which would help during implant placement. The aim of this review article is to collect the information regarding the effects of HBO on periodontal diseases and dental implants. In conclusion, this review has shown that HBO may represent a useful aid, especially in combination with scaling and root planning (SRP), as far as nonsurgical periodontal therapy is concerned.

Keywords: Hyperbaric oxygen therapy, Implants, Periodontal diseases.

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Introduction

Periodontal diseases are caused primarily by pathogenic bacteria. The presence of putative periodontal pathogens in the gingival crevice is not sufficient to initiate the inflammation process. Elevation of the relative proportions of these bacteria plays a crucial role in causing tissue and bone damage.[1]

Nowadays, various novel therapeutic approaches are tried as an alternative to conventional therapy or in combination with conventional therapy to reduce the load of periodontopathic pathogens. One of the effective therapeutic measures can be the use of hyperbaric oxygen, $n(HBO_2)$.[2]

Although the application of compressed gas in medicine had its origin centuries ago, the use of hyperbaric therapy dates back nearly 350 years. The first hyperbaric chamber was created in 1662; today, studies continue to improve and find more uses for hyperbaric oxygen (HBO) therapy.[3]

Hyperbaric literally translates to increased (hyper) pressure (baric). At the sea level, a person is being exposed to normal atmospheric pressure or 1 atm and breathes approximately 21% oxygen. In a hyperbaric chamber, this is increased to 100% oxygen and 1.5–3× normal atmospheric pressure. This allows the blood to carry more oxygen and deliver 15–25 times more oxygen to the tissues and organs of the body. Oxygen has natural healing properties, and increasing the amount that is circulating throughout the body promotes faster and more efficient healing for a wide variety of diseases and ailments. It also provides numerous health benefits.[2,4]

Mechanism of Action

Therapeutic effects of HBO can be attributed to its mechanical or hyperoxygenation effects:[5–31]

Hyperoxygenation

The effect of oxygen–hemoglobin reaction on the transportation of CO_2, known as "Haldane" effect, results from the fact that a combination of oxygen with hemoglobin causes it to become a stronger acid. This displaces CO_2 from the blood in two ways: first, when there is more acid, hemoglobin has less tendency to combine with CO_2 to form carbhemoglobin. Much of the CO_2 present in this form in the blood is, thus, displaced and, second, the increased acidity of the hemoglobin causes it to release an excess of H^+ ions, and these, in turn, bind with bicarbonate ions to form carbonic acid which then dissociates into water and CO_2, which is released from the blood into the alveoli.

Bubble Size Reduction

High air pressure decreases the volume of gas bubbles in the blood 2–3 times that of normal air pressure. High oxygen (100%) intake saturates the blood plasma with oxygen. It is the primary mechanism at work in the management of decompression sickness and arterial gas embolism.

Vasoconstriction

Elevated levels of oxygen cause vasoconstriction that leads to a reduced blood flow without significantly affecting tissue oxygenation. HBO is used to control compartment pressures in crush injuries and to treat thermal burns.

Fibroblast Proliferation/Collagen Synthesis

Oxygen is essential to make and properly organize collagen. Organized collagen is bundled into fibers (like strands in rope), which are interwoven and can be stretched in multiple directions without tearing (the collagen fibers are woven similar to fabric).

Department of Periodontics, Sharda University, Greater Noida, Uttar Pradesh, India

Corresponding Author: Harshita Gupta, Department of Periodontics, Sharda University, Greater Noida, Uttar Pradesh, India, Phone: +91 9910368352, e-mail: gupta_harshita28@yahoo.com

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- Multiple patients treated per session.
- Greater working pressure.

Disadvantages

- Higher capitalization requirements.
- Major space requirements; basement and/or ground floor level limitations.
- Higher operating costs.

Monoplace Chambers

They were designed for single occupancy and usually constructed of acrylic, having a pressure capability of 3.0 ATA, and compressed with 100% oxygen. The high flow oxygen requirement is ideally supplied via a hospital's existing liquid oxygen system (Figs 1 and 2).

Advantages

- Cost-efficient delivery of HBO_2.
- No risk of decompression sickness.
- Portable, less space, less equipment, no hood, or mask.
- No risk of iatrogenic decompression sickness in patient or staff.

Disadvantages

- Relative patient isolation.
- Associated fire hazard.
- Inability to use certain diagnostic and/or therapeutic equipment.

Silicon Trays

These trays are made up of silicon and oxygen can be supplied to these trays via an anterior valve. The silicon trays are trimmed to the right length and should be adjusted to the individual patient to create a tight fit with the mucous membrane while allowing the oxygen unimpeded access to the gingiva (Fig. 3).

Indications

- Air or gas embolism.
- Carbon monoxide poisoning or carbon monoxide poisoning complicated by cyanide poisoning.
- Clostridal myositis and myonecrosis (gas gangrene).
- Crush injury, compartment syndrome, and other acute traumatic ischemia.
- Decompression sickness.
- Enhancement of healing in selected problem wounds: diabetically derived illness, such as diabetic foot, diabetic retinopathy, and diabetic nephropathy.
- Exceptional blood loss (anemia).
- Intracranial abscess.
- Necrotizing soft tissue infections (necrotizing fasciitis).
- Osteomyelitis (refractory).
- Delayed radiation injury (soft tissue and bony necrosis).
- Skin grafts and flaps (compromised).
- Thermal burns.

Contraindications

Absolute Contraindications

- Untreated pneumothorax
- Bleomycin
- Cisplatin
- Disulfiram
- Doxorubicin
- Sulfamylon

Relative Contraindications

- Asthma
- Claustrophobia
- Congenital spherocytosis
- Chronic obstructive pulmonary disease (COPD)
- Eustachian tube dysfunction
- High fever
- Pacemakers or epidural pain pump
- Pregnancy
- Seizures
- Upper respiratory infection (URI)

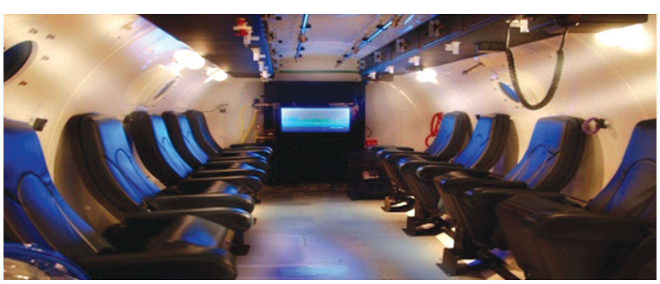

Fig. 1: Multiplace chamber

Fig. 2: Monoplace chamber

Fig. 3: Silicon trays (maxilla and mandible)

HBO and Implant

Dental implants offer a way to replace missing teeth. Patients who have undergone radiotherapy or surgery may benefit from reconstruction with implants.

Mechanism

HBO has been shown to affect angiogenesis, bone metabolism, and bone turnover. In relation to radiotherapy, HBO_2 can, thus, counteract some of the negative effects of irradiation and actually act as a stimulator of osseointegration. The exact mechanisms at the cellular level where HBO_2 acts remain obscure. It has been recently shown that HBO_2 and basic fibroblast growth factor (bFGF) acts synergistically in the irradiated bone. Factors that could be involved in bone protection by bFGF and HBO_2 are bone marrow radioprotection, induction of oxygen radical scavengers, and production of different cytokines.

HBO and bFGF can also enhance the level of insulin growth factor, which is known to promote proliferation and differentiation of bone. They could also affect bone progenitor cells by promoting DNA synthesis, stimulating enzymes involved in bone formation, or affect membrane receptors. HBO_2 has furthermore been shown to affect the interface between the titanium implant and the bone, which could be different from the cellular effect.

Oxygen under hyperbaric conditions could, thus, play a role in osseointegration by affecting bone cell metabolism, implant interface, and capillary network in the implant bed.

Evidence

Taylor and Worthington[49] reported that when implants were placed in conjunction with HBOT, healing was more reliable, although still slow. They recommended HBO_2 for patients treated with >50 Gy.

Johnsson[50] investigated the influence of a single 15 Gy dose of irradiation on the capacity of titanium screws to integrate with the irradiated bone tissue. The biomechanical force necessary to unscrew the titanium implants 8 weeks after placement was 54% lower for implants in irradiated bone tissue compared to implants in nonirradiated bone tissue. Postirradiation use of HBO treatment at 2.8 ATA (2 hours daily treatments for 21 days) increased the biomechanical force necessary to unscrew the titanium implants by 44% in the irradiated bone and by 22% in the nonirradiated bone.

Andersson et al.[51] concluded that the implant treatment for oral rehabilitation can be carried out as a safe and successful procedure in the irradiated patient without adjunctive HBO therapy. Marx and Morales[52] reported a 5-years survival in 622 out of 748 osseointegrated implants after HBO_2 treatment.

Granström et al.[53] in a case-controlled study found that about 53.7% implants failed in the irradiated group compared to 13.5% in the nonirradiated group and 8.1% for the irradiated HBO_2-treated group. He concluded that the implant insertion in the irradiated bone is associated with a higher failure rate. Adjuvant HBO treatment can reduce the failures. Johnsson et al.[54] concluded that irradiation reduces the capacity for osseointegration of titanium implants. HBO treatment may improve bone formation and, especially, has positive effects on bone maturation after irradiation.

Granstrom[55] and Teoh et al.[56] concluded that the adjunctive use of HBO treatment with implant installation is strongly recommended. Brandt and Balanoff[57] concluded that using an accepted hyperbaric oxygenation protocol when placing and restoring immediate implants in their case report resulted in a successful treatment outcome.

Esposito et al.[58] and Coulthard et al.[59] in a systematic review found only one randomized controlled trial (RCT) comparing HBO_2 with no HBO_2 for implant treatment in irradiated patients and they concluded that HBOT in irradiated patients requiring dental implants may not offer any appreciable clinical benefits. There is a definite need for more RCTs to ascertain the effectiveness of HBO_2 in irradiated patients requiring dental implants. Grecchi et al.[60] in the case of mandible osteonecrosis after a severe peri-implant infection observed that the risk of developing osteonecrosis of the jaw for oral implants is low after HBO therapy. Nyberg et al.,[61] Chambrone et al.,[62] Wadhawan et al.,[24] and Shah et al.[63] concluded that the HBO can be the effective treatment protocol for the implant treatment in irradiated maxillofacial patients.

Conclusion

HBO has been successfully used in several medical applications. It has been described as “a therapy in search of diseases.”

Several studies have described the beneficial role of HBO in the treatment of various human pathologies either alone or in combination with other therapies. Very few studies have been conducted to analyze the effects of HBO therapy on periodontal disease. Although available evidences are few, HBOT was shown to improve gingival blood flow and microcirculation and inhibit the growth of periodontal pathogens in periodontal pocket when used alone or in combination with conventional periodontal therapy. In future, further research is required to be conducted to prove potential benefits of HBOT.

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