

## Hyperbaric Oxygen: Can it be a Beneficial Adjunct in Periodontitis???

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### Abstract

**Introduction:** Although the use of pressurized air in attempts to treat disease has a history of more than 300 years, the scientific foundation for hyperbaric oxygen therapy was laid in the 1960s when Brummelkamp, Hogendijk, and Boerema- reported the use of this treatment modality for gas gangrene. Since then, numerous investigations and clinical experience have demonstrated the efficacy of hyperbaric oxygen in a number of disorders.

**Review of Literature:** Maturation and cross-linking of collagen increases linearly with an ambient oxygen concentration. Current protocols for HBO therapy are empirical; the mechanism of action and optimal therapeutic use of HBO remain poorly understood. The knowledge of the most appropriate design of this therapy is hindered by the lack of detailed mechanistic information on the effects of HBO on constituent cells in the wound-healing process.

**Clinical Relevance:** The adjunctive use of HBO therapy can positively alter the compromised wound healing process. Exposure of patients to HBO increases the amount of oxygen that is present within tissue. Delivery of oxygen from the ambient air to the cardiovascular system and eventually to the mitochondria is described as the oxygen pathway. Studies also have got positive result when used in chronic periodontitis patient and in implant therapy. It accelerates wound healing in flap surgery in periodontitis patient.

**Conclusion:** Although the data on the effect of varying chamber pressure are incomplete, there is evidence that enhanced oxygenation occurs at lower pressures than the standard 2.4 ATA, and that higher pressures may be damaging to cells. If these initial findings are confirmed by further studies, it may be possible to obtain optimal healing of superficial vascularized wounds by fewer and shorter HBO treatments, perhaps at lower chamber pressures. Such a change in the therapeutic regimen could reduce the incidence of undesirable effects while also reducing costs.

**Keywords:** Hyperbaric Oxygen; Wound Healing; Mono Chamber; Multiphase Chamber

### Introduction

Hyperbaric Oxygen Therapy (HBOT) is increasingly being accepted as a beneficial adjunct to diverse clinical conditions. Non-healing ulcers, chronic wounds and refractory osteomyelitis are a few conditions for which HBOT has been extensively tried out and nowadays periodontitis and dental implants have also been tried out.

Hyperbaric oxygen's definition is short term - "100% oxygen inhalation therapy at a pressure greater than that of sea level". 2.4 absolute atmospheres or ATA is almost the pressure. When oxygen is used as a drug, the dose is controlled by the technology of a hyperbaric oxygen chamber which sets the dosage at 100% oxygen and also controls the drug absorption by the pressure in the chamber. Like any drug, too little of a dose may result in a sub therapeutic result, while too great a dose may result in toxicity.

In the reparative cases molecular oxygen is the crucial nutrient of the wound. During the reparative cases collagen synthesis, matrix formation, angiogenesis, epithelialization and bacterial killing all require molecular oxygen. During collagen synthesis, oxygen; is a substrate for the hydroxylation lysine and proline, a step required the release of collagen from cells. Under anoxic conditions, fibroblast produces an intracellular collagen precursor, but fail to release it.

### Review of Literature

#### Hyperbaric oxygenation physiology

At normal sea level partial pressures of oxygen, when the alveolar and arterial  $P_{O_2}$  are approximately 100 mm Hg, hemoglobin is about 97% saturated with oxygen. This yields oxygen content in arterial blood of approximately 20 vol %. Oxygen is also physically dissolved in plasma to the extent of 0.31 vol% per 100 mm Hg  $P_{aO_2}$ . As the partial pressure of inspired oxygen increases, the hemoglobin quickly becomes 100% saturated and increasing amounts of oxygen are physically dissolved in plasma. At 3 atmospheres absolute pressure (ATA) or 2180 mm Hg, when 100% oxygen is breathed, approximately 6 vol% of oxygen is physically dissolved. More important, however, is that the  $P_{aO_2}$  is greater than 1900 mm Hg, establishing a steep diffusion gradient between the capillaries and the surrounding tissue. This steep gradient allows oxygen to diffuse farther from functioning capillaries, permitting physiologic levels of tissue oxygen tension to be achieved in poorly perfused tissue.

This requirement for oxygen in wound healing is the rationale for hyperbaric oxygen (HBO) therapy. It results in an increase in tissue oxygen tension and improves collagen synthesis, angiogenesis, epithelialization, and resistance to bacteria in problem wounds. Since these processes are closely related to tissue oxygen tension, relieving wound hypoxia with HBO therapy accelerates wound healing by increasing the oxygen tension [1].

#### Mechanism

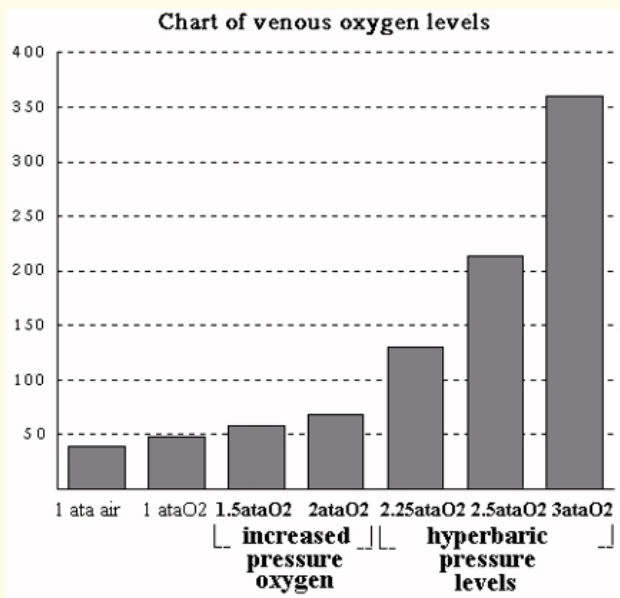
High arterial  $O_2$  appears to drive angiogenesis into hypoxic spaces in coordination with fibroblast collagen production and the release of an angiogenic substance by macrophages. Hypoxic wounds are also susceptible to infections. Neutrophils and macrophages can phagocytose bacteria, but their bactericidal ability is impaired by hypoxia and the inability of neutrophils to produce oxygen radicals. Bacteria may flourish and further increase the demand for oxygen in an already hypoxic wound.

The adjunctive use of HBO therapy can positively alter the compromised wound healing process. Exposure of patients to HBO increases the amount of oxygen that is present within tissue. Delivery of oxygen from the ambient air to the cardiovascular system and eventually to the mitochondria is described as the oxygen pathway. The  $P_{O_2}$  is decreased at each step of this pathway. The oxygen cascade describes this decrease in  $P_{O_2}$  from 160 mmHg in dry ambient air to 1 - 3 mmHg in the mitochondria. The capability of HBO therapy to increase the delivery of oxygen may be appreciated by comparing the  $P_{O_2}$  at different sites in the oxygen pathway. The alveolar partial pressure of oxygen ( $P_{A_{O_2}}$ ) is approximately 102 mmHg while breathing air at atmospheric pressure. The  $P_{A_{O_2}}$  can be increased to 673 mmHg while breathing 100% oxygen, and to 1813 mmHg while breathing 100% oxygen at 2.5 ATA, an 18-fold increase over breathing air at atmospheric pressure. This additional oxygen is distributed by the circulating blood primarily dissolved in the plasma. This correlates with an increase in the wound tissue  $P_{O_2}$  from 5 - 20 mmHg while breathing air at 1.0 ATA to 200 mmHg while breathing 100% oxygen at 1.0 ATA to a  $P_{O_2}$  of 800 - 1100 mmHg while exposed to 100% oxygen at 2.5 ATA.

#### How does being inside a pressurized chamber for a limited time period (around 60 minutes) help humans heal?

While inside a chamber pressurized with 50% more air pressure we breathe 50% more molecules. Breathing nearly pure oxygen in such a chamber gives us about 7½ times more oxygen than we normally breathe. In one hour we can inhale 1½ pounds of oxygen. Oxygen

gets filled into red blood cells instantly but, the extra oxygen gets dissolved into the plasma. Plasma, not red blood cells, holds the key. This extra oxygen helps tissues deficient in oxygen regain proper oxygen levels. This action stimulates healing both during and after the session. During the session oxygen activates the reticulo-endothelial system. After the session normal homeostatis promotes healthy function by stimulating adaptation to the relative lower, but normal, levels of oxygen. In order to raise tissue oxygen tension above 50mm Hg for this healing stimulus one must have nearly pure oxygen delivered under slightly increased atmospheric conditions. Graph 1 depicts venous oxygen levels.



Graph 1: Venous oxygen levels.

The chart here, closely represents the final tissue oxygen tension, observe the venous oxygen tension rise when breathing oxygen beginning at 1½ atmospheres of increased pressure. A linear increase in tissue oxygen levels occur between 1 and 2 atmospheres absolute (ata). Once the atmospheric pressure increased beyond 100% more than normal (2 ata) there was a geometric rise. Above this level increased tissue oxygen enters the hyperoxia range and requires more supervision as nerve sensitivity to extreme oxygen can bring on temporary side-effects. This sensitivity does not occur at low pressures (below 1¾ ata) as the body can self-regulate circulation to allow more oxygen to tissues that need it while slowing oxygen flow to areas that have enough.

**Hyperbaric chambers**

The effects of compressed oxygen Dr. John S. Haldane were studied and taught at the University of Dundee in the early 1900's. The first diving tables for the Royal Navy were developed by him. He is popularly known as "Father of Oxygen Therapy". In 1918 Dr. Orval Cunningham considered the differences between people living or dying through the flu epidemic in the Rocky Mountains. He noticed people in the mountains are better than people in the valley. The incidence of infection was less due to denser air in the valley. He was the one to make the world's largest functional hyperbaric chamber and a hyperbaric hospital with five floors of living space.

**Chambers**

Both monoplace (Figure 1) and multiplace (Figure 2) hyperbaric oxygen chambers are there.

**Monoplace chamber**

- Claustrophobic environment
- Limited access to patient
- Whole chamber contains hyperbaric oxygen
- Lower cost
- Portable



*Figure 1: Monoplace chamber.*

**Multiplace chamber**

- More room; assistant can enter to deal with acute problems such as pneumothorax.
- Hyperbaric oxygen via tight fitting mask chamber gas can be air (reduced fire risk).



*Figure 2: Multiplace chamber.*

### Does the increased pressure cause discomfort?

Hyperbaric treatments are painless. The sensation of “fullness” occurs as the eardrums respond to the change in pressure which is similar to driving down a mountain, flying, or scuba diving.

### What are some preparations before HBO therapy?

**Medications:** With hyperbaric oxygen therapy some of the medications are not compatible which includes:

- Prednisone
- High doses of aspirin
- Morphine
- Alcohol within 8 hours of treatment
- Patients who are taking insulin
- Tranquilizers
- Anticoagulants.
- Vitamin E
- Other antioxidants course
- Smoking as Nicotine is another substance that is not compatible
- Cosmetics: Cosmetics, hair spray, nail polish, perfume, or shaving lotion containing a petroleum, alcohol or oil base are not allowed.

**Clothing:** Patients are provided with 100-percent cotton gowns to wear during treatment.

### Protocol of hyperbaric oxygen for elective surgery

Studies have identified that hyperbaric oxygen cannot advance normal wound healing in uncompromised tissue beyond its usual rate or degree. This is due to the inherent oxygen gradients in normal wounds which are of the order of 30 - 55 mmHg. However, in select damaged tissues which have a field effect and therefore naturally low oxygen gradients (radiated tissues, diabetic tissues, crush injuries, etc.) it creates an oxygen gradient sufficient to generate macrophage-directed wound healing and revascularization.

### Applications

#### Therapeutic uses of hyperbaric oxygen

##### Main treatment

- Decompression sickness
- Arterial gas embolism
- Severe carbon monoxide poisoning and smoke inhalation.

##### Adjunctive treatment

- Prevention and treatment of osteoradionecrosis
- Improved skin graft and flap healing
- Clostridial myonecrosis
- Refractory osteomyelitis
- Radiation induced injury
- Acute traumatic ischaemic injury
- Prolonged failure of wound healing
- Exceptional anaemia from blood loss.

### Hyperbaric oxygen and flaps

The role of the elective hyperbaric oxygen protocol when either muocutaneous or free vascularized soft tissue or bone transfers are employed in radiated tissue is to develop a vascular and cellular tissue bed into which these flaps can heal. An interrupted or incomplete oxygen protocol doesn't develop its maximal angiogenic benefit and therefore place the patient at greater risk for wound dehiscence, wound infection and delayed wound healing. Related to wound infections the pattern of results was similar.

### Chronic periodontitis in animal study model

The effect of increased blood oxygen tensions on artificially induced periodontal disease was studied. Periodontal pathology induced in dogs, a process thought to be caused primarily by anaerobic bacteria, was treated with hyperoxygenation. By the means of a hyperbaric oxygen chamber blood oxygen tensions were elevated to at least for two hours twice a day, two days a week for four weeks. Then in treated and untreated animals clinical appearance and loss of alveolar bone was recorded.

At the end of 8 weeks it was found that animals receiving hyperbaric oxygen had gingival tissues which appeared clinically healthy and were associated with modest bone loss. The control animals had grossly inflamed gingival more oftenly and there was marked loss of bone after completion of 8 week period.

Chen T., *et al.* (2002), noticed the effects and the mechanism of hyperbaric oxygen on prostaglandin E (2) levels. The results showed that the difference of PGE (2) in gingiva or alveolar bone of the HBO group were statistically significant than in non HBO group. The authors concluded that the contents of PGE (2) in alveolar bone and gingiva increased markedly when experimental periodontitis was formed [2].

Chen T., *et al.* 2002, noticed the effects of Hyperbaric Oxygen in a controlled study of periodontitis in twenty four patients. The study was divided into 4 groups based on treatment: group1- HBO [2] therapy, group 2- HBO [2] + scaling, group 3-scaling and group 4-control. The gingival indices were measured. The microorganisms in a periodontal pocket were stained and the percentage of straight rods (Rods), curved rods (Cur), fusiforms (Fusi) and spirochetes (Spiro) were observed. Highly significant differences Probing Depth (PD), Attachment Loss (AL), in Gingival Indices (GI), Sulcus Bleeding Indices (SBI), Plaque Index and (PII) were seen in the HBO [2], the HBO [2] + Scaling and the Scaling Groups compared to the Control Group ( $P < 0.01$ ). The most beneficial in the treatment of periodontitis was combined HBO [2] therapy with scaling and root planing. This treatment could last for more than one year which is suggested by a clinical follow-up [3].

Another study was conducted on sixty Aggressive periodontitis patients to investigate HBO2 on AgP and subgingival obligate anaerobes in Chinese patients. Highly significant results in gingival index and probing depth for patients with scaling and HBO2 then only scaling

### Dental implants

Another and a more recent application of the elective surgery hyperbaric oxygen protocol is in the placement and enhanced success rate of dental implants. Today dental implants are frequently used not only in the mandible and maxilla for dental rehabilitation, but also for anchorage when facial units are replaced, such as eyes, ears or nose prosthesis. The protocol of 20 sessions of hyperbaric oxygen prior to dental implant placement followed by 10 sessions after placement is recommended. In these cases, the hyperbaric oxygen-induced angiogenesis prevents a high incidence of surgical complications leading to overt osteoradionecrosis, while the fibroplasia effects stimulate osteogenesis about the implant surface to improve osseointegration. To date no randomized prospective implant studies with implants and hyperbaric oxygen have been completed [5]. However, the experience at the University of Miami Division of Oral and Maxillofacial Surgery has been one of 918 implants placed into radiated bone having received greater than 6000 cGy in 316 patients. After 1 year 771 were osseointegrated and functional (83.9%), at 2 years 768 (83.6%) and at 3 years 762 (83.0%). Only two cases progressed into osteoradionecrosis (0.6%). During this same time period 34 cases of implants were placed into bone radiated to the same dose range involving 92 implants. After 3 years only 44 implants are still osseointegrated and functioning (47.8%) and 11 cases developed osteoradionecrosis (32.4%).

### Potential complications of hyperbaric oxygen

Hyperbaric oxygen has very few absolute and relative contraindications to its use. The two established protocols outlined in this chapter represent time-tested protocols which have been proven safe as well as effective. However, hyperbaric oxygen, like any drug, is not tolerated by everyone nor meant for everyone. The two observed absolute contraindications to the use of hyperbaric oxygen are optic neuritis and immunosuppressive disorders. Chronic obstructive pulmonary disease and claustrophobia are the relative contraindications. Those individuals with acute upper respiratory tract inflammations, 'common colds', or those who cannot clear their ears for any other reason are contraindicated.

### Conclusion

Conditions that have low oxygen in the tissues are helped by the hyperbaric oxygenation. Skin grafts which are compromised often improve with hyperbaric oxygenation. Lately antibiotic therapy which failed to clear today's resistant strains of pathogens became of interest as they were affected by HBOT. No doubt the use of this elective surgery protocol of hyperbaric oxygen has proven outcome efficiency in both scientific studies and clinical experience but still research is further needed to extend the pros and cons of the process.

### Conflicts of Interest

No conflicts of interest.

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