

Clinical utility of hyperbaric oxygen therapy in dentistry

Kaitlyn Re¹, Shrey Patel¹, Jason Gandhi^{1,2}, Yiji Suh¹, Inefta Reid³, Gunjan Joshi³, Noel L. Smith⁴, Sardar Ali Khan^{1,5,*}

¹ Department of Physiology and Biophysics, Stony Brook University School of Medicine, Stony Brook, NY, USA

² Medical Student Research Institute, St. George's University School of Medicine, Grenada, West Indies

³ Department of Internal Medicine, Stony Brook Southampton Hospital, Southampton, NY, USA

⁴ Foley Plaza Medical, New York, NY, USA

⁵ Department of Urology, Stony Brook University School of Medicine, Stony Brook, NY, USA

*Correspondence to: Sardar Ali Khan, MD, FRCS, FACS, skysalik@gmail.com.

orcid: 0000-0002-4759-530X (Sardar Ali Khan)

Abstract

This fuller impact of the use of hyperbaric oxygen therapy within dentistry is taking greater notice with newer research findings. There are new advancements in research regarding postradiotherapy cases, osteonecrosis of the jaw, osteomyelitis, periodontal disease, and dental implants. Hyperbaric oxygen therapy can even be used in conjunction with other procedures such as bone grafting. Although the research and clinical utility has come a long way, there are several complications to be mindful of during the application of hyperbaric oxygen therapy.

Key words: hyperbaric oxygen therapy; dentistry; osteoradionecrosis of the jaw; dental implants; periodontal disease; oral submucous fibrosis; mandibular osteomyelitis

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INTRODUCTION

Hyperbaric oxygen therapy (HBOT) facilitates the transfer of oxygen to the tissues of the human body. By doing so, it promotes healing of wounds and minimizes the typical recovery time for patients.¹ At this juncture, strictly within dental medicine, HBOT indicates the distribution of comprehensive oxygen at pressures greater than 1.4 atmosphere absolute (ATA), often in a series of treatments.² This treatment requires the patient to stand within a hyperbaric chamber with pressure greater than ambient. It has many uses such as patient care, and wound care within standard medicine and dental medicine.³

HBOT exploits numerous physiological principles of how gases and oxygen react under specific adjustments of pressure. There is a direct relationship between the concentration of oxygen in solution and the diffusion gradient. The increase in concentration of oxygen in solution results in the increase of the diffusion gradient for the delivery into deeper tissue, thus being the basis for HBOT. Henry's law defines that at constant temperature, the concentration of gas that is dissolved in a given liquid is proportional to the partial pressure of the gas above the fluid.⁴ In HBOT, the oxygen level is amplified, which highly increases the oxygen tension in the tissues. When the treatment is concluded, the oxygen tension decreases allowing for an inundation of neutrophils. Neutrophils are a type of white blood cells which specifically aid in fighting off infection and tissue regrowth.⁵ Conclusively, the increase in dissolved oxygen generated by HBOT has potential to alter tissue responses to disease and injury. In some cases, this may prevent death and or amputation of limbs.⁶ HBOT is most commonly executed at a compression rate of 0.067 ATA/min (6.8 kPa/min). However, a study conducted in 2007 concluded that the pressure equal-

ization can lead to middle ear pain and or discomfort, cranial sinus pain, and teeth pain. It is recommended that specific care must be implemented with patients who suffer from peripheral circulatory disorders and have short interval between clinical symptoms, as per Hirsch and Watson and the American College of Cardiology/American Heart Association guidelines.⁷

HISTORY

The use of HBOT can be dated back to the 1600s; however it was unverified until 1956. Ite Boerema, the chief of surgery at University of Amsterdam, The Netherlands is known for his success while using HBOT to lengthen safe operating times during cardiac surgery.⁸ By 1960, records show that there was a drastic decrease in mortality rate from 66% to 23%. Records also indicate that HBOT excessively decreased the invalidity rate, which demonstrates its ability to save both life and limb.³

HBOT utilizes several physiologic principles of how gases respond under pressure and more specifically of how oxygen responds under pressure. The increase in concentration of oxygen in solution, based on its solubility under pressure, raises the diffusion gradient for its delivery into deep tissues, which is the premise of HBOT. Ultimately the increases in dissolved oxygen generated by hyperbaric therapy have several physiologic effects that can alter tissue responses to disease and injury. As this technology becomes more available to clinical practice, HBOT should be considered as a therapeutic option.

The study of physiology under inflated pressures is said to have begun in 1644 by an Italian physicist Evangelista Torricelli, who invented the first barometer. The collaboration between Galileo, Blaise Pascal, Robert Boyle, and Robert Hooke lead to the discovery of the inverse relationship between



pressure and altitude. Hooke is responsible for creating the first air pump that eventually helped facilitate the creation and discovery of HBOT.⁹

Therapeutic Principles

The fundamental mechanism for HBOT depends on the intracellular inception of reactive species of oxygen and nitrogen. Cell signaling transduction cascades within this mechanism signify the importance of the reactive species, oxygen and nitrogen.¹⁰ The reactive species of oxygen and nitrogen work together to cause oxidative stress by damaging the cells.

Uses in Dentistry

While it has various uses specific to dental medicine, HBOT is most often used for prevention of complications during radiation therapy.¹¹ It is known to effectively increase tissue oxygenation and, moreover, expedite the healing of wounds.¹² The healing of wounds is especially significant in periodontal disease and oral submucous fibrosis.¹³ Recent studies on the role of HBOT in the management of necrotizing fasciitis, wound dehiscence after intraoral bone grafting in non-irradiated patients, osteoradionecrosis of the mandible, and oral submucous fibrosis are crucial for recognizing the future scope of impact HBOT in dentistry.¹⁴ In specific, necrotizing fasciitis is a flesh-eating disease, as the infection commonly leads to death of parts of the body's soft tissue. This disease spreads rapidly and requires immediate aggressive surgical management and an extended debridement. In some cases, early amputation is required.¹⁵ Wound dehiscence, the separation of the edges of a surgical incision, requires the doctor to clean and debride the lesion to remove the dead and infected tissue, in which amplifies the healing process. The most important aspect of this is expediting the healing process in which prevents further complications such as surgical site infections.¹⁶ HBOT has the potential to prevent the following complications that co-occur with necrotizing fasciitis and wound dehiscence.

HBOT is an effective utilization in various chronic radiation-induced tissue injuries. Osteoradionecrosis prophylaxis resulting from a radiation-induced dental disease had an underlying response rate of 96%. The overall response rate for soft tissue necrosis and hemorrhagic cystitis was 84%.¹⁷ **Table 1** lists the use of HBOT in dental cases with respect to radiotherapy.¹⁸

Osteoradionecrosis

Osteoradionecrosis of the jaw is commonly acknowledged as death of the jaw bone and bone within the head and neck region because of the decreased oxygen tension-hypotension hypocellularity and hypovascularity. Osteoradionecrosis is a

nonhealing, nonseptic lesion of the bone in which bone volume and density cannot be maintained by the hypocellular, hypovascular, hypoxic tissue, which cannot adequately meet its metabolic demands. As the soft tissue decays, the bone begins to become exposed. Saliva and other foreign entities within the oral cavity will prompt cross-contamination, thus leading to significance in infection and further complications.¹⁹ Symptoms of osteoradionecrosis include mouth pain, jaw swelling, poor smelling breath, mouth sores, and difficulty opening the jaw.^{20,21}

In 2013, a study was done regarding HBOT and mandibular osteoradionecrosis during tooth extractions. It was determined that HBOT provided adequate prevention.²² HBOT in conjunction with penicillin proceeding tooth extraction proved to have a more efficient and longer lasting recovery in comparison to the patients exclusively treated with penicillin. Time sensitivity is imperative – if the treatment of HBOT is administered 2 weeks prior to the dental treatment, complications arise in 1.5% to 4.2% of the patients.²³ If the treatment is prolonged to six months prior to the dental treatment, the percentage of complications increases to 15.8%. Osteoradionecrosis often yields an array of serious side effects. These include facial deformity, pain, pathological fracture, sequestration of devitalized bone, and orocutaneous fistulas.²⁴ Dysgeusia, paresthesia, bone exposure, gingival ulceration, tooth fracture, pathologic mandibular fracture, xerostomia, and orocutaneous fistula are common within the oral cavity. All of the following induce extreme irritation and pain, and often lead to more severe complications if not treated in a timely manner.²⁵ HBOT increases the oxygen tension in the region and promotes angiogenesis, the development of new blood cells. The development of new blood cells directly leads to wound healing. When a wound is beginning to heal, the angiogenic capillaries sprout and invade the fibrin-rich wound clot. When the clot is invaded, the alpha v beta 3 receptors are targeted, which are necessary for wound healing.²⁶

Osteoradionecrosis is often diagnosed in three different stages: spontaneous, from trauma preceding radiotherapy, and due to trauma post-radiotherapy. In the spontaneous stage, the high dose of radiation during treatment can directly lead to death of the bone cells, destroying the bone. Radiation of > 700 cGy is considered enough to immediately kill the bone cells after one full year. In trauma preceding radiotherapy, often times this leads to radiotherapy for oral cancers or mandibulotomy. Trauma post-radiotherapy is very common, especially after dental extractions. Tooth extractions normally follow severe infection and inflammation of gum tissue surrounding the tooth.²⁷ After a tooth is extracted, the tissues become 3-H

Table 1: Dental cases treated with hyperbaric oxygen therapy

Clinical condition	Number of cases	Mean time since radiotherapy	Time range	Number of hyperbaric oxygen therapy sessions (mean)	Time range
Osteoradionecrosis	3	6.7 months	3 to 10 months	34	12 to 38 months
Post-radiotherapy cases	3	54 months	8 to 60 months	11	10 to 14 months
Mandibular osteomyelitis	5	N/A	N/A	28	17 to 40 months

Note: N/A: Not applicable.



with advancing years, typically 3. As the radiation affects progress, the tissue cannot handle the increase in vascular nutrition and oxygen demands that are required for healing. If the tissue cannot heal, osteoradionecrosis will develop.²⁸

A Marx protocol was created for the treatment of ORN within the jaw, that includes three critical stages. Stage I of this process requires setting the HBOT level to 2.4 ATA for a total of 90 minutes. After a third of the session is completed, it is necessary to inspect the targeted area for softening of exposed bone and granulation tissue. If the following are present, it is suggested to follow up with non-surgical debridement and follow up with an addition of 10 HBOT sessions. Stage II is necessary only if little or no response is observed after the previous 30 sessions of treatment. Stage II requires peripheral resection of non-vital bone to bleeding bone margins, followed by 10 postoperative sessions of HBOT. Stage III recommends resection of the mandible after 30 ineffective sessions of HBOT. Add plates and pins and covering the soft tissue deficit will help to stabilize the mandible. The 10 subsequent treatments of HBOT and 3 months of healing are recommended. At this point, bone remodeling can be completed.²⁹

Post-radiotherapy cases

Postradiation therapy can both improve quality of life and increase average life span of those suffering from post-radiation central nervous system injury. Various experiments have concluded that HBOT does in fact stimulate improvements in subjective, clinical, and radiological outcomes.³⁰ Sometimes, radiation such as HBOT can bring upon xerostomia on those treated. Xerostomia is defined as dry mouth resulting from reduced or absent saliva flow. Radiation therapy, such as HBOT, often damages salivary glands while also treating the diagnosed issue.³¹ Radiation-induced xerostomia is one of the most common morbidities of radiation therapy in patients with head and neck cancer. The more important conclusion is that HBOT often helps to cure and heal those diagnosed with head and neck cancer, explaining why the xerostomia is often overlooked.³²

High concentration of radiotherapy in conjunction with chemoradiation therapy promotes and expedites damage of tissue cells and vasculature. HBOT raises oxygen levels in hypoxic tissue, stimulates angiogenesis and fibroplasias, and is an effective and powerful treatment for postoperative wounds in oral, pharyngeal, and laryngeal carcinoma surgeries.³³ In contrast, HBOT has also been proven to help those suffering with hyposalivation, a salivary gland hypofunction. Studies show that patients with hyposalivation may also face complications in regard to active respiratory infection. There were 60.4% of the 274 studied facing challenges associated with acute respiratory infection and hyposalivation while 35.5% of the 274 patients only suffered from hyposalivation. The human mouth serves as the only direct entranceway into the respiratory apparatus, thus leading to the digestive tract.³⁴

HBOT is considered an effective treatment amongst those suffering as it has the potential to reduce medical and dental treatment costs and limit the negative effects of radiation amongst those suffering, thus improving the patient's quality of life.³⁵

Mandibular osteomyelitis

Mandibular osteomyelitis is a rare, non-suppurative, chronic inflammatory disease of an unknown genesis that is associated with the bone marrow, cortical bone, periosteum, as well as blood vessels and nerves.³⁶ It is an unresponsive infection that results from dormant bacteria. It is commonly distinguished as an area with minimal pus formation, fistula, or bony sequestrate formation.³⁷ After HBOT admission, patients have reported lack of both pain and swelling. The average patient has received 40 treatments.³⁸ HBOT works by favoring the action of the inflammatory cells and increases the host response to the targeted pain and swelling. A study conducted in 2008 proved that HBOT has an 80% success rate with a 21-day treatment.³⁹ It can be concluded that HBOT is powerful in conjunction to aggressive medical and surgical treatment.⁴⁰

Periodontal disease

Periodontal disease is a chronic inflammatory condition of the supporting structure of the teeth.⁴¹ The most common cause of periodontal disease is the accumulation of bacterial plaque. If the plaque is not removed, it hardens into calculus and tartar which eventually leads to periodontal disease. Periodontal disease disturbs the soft tissues and bone that support the teeth. In periodontitis, pathobionts, and keystone pathogens such as *Porphyromonas gingivalis* appear in greater proportion than in health.⁴² As a keystone pathogen, *P. gingivalis* impairs host immune responses and appears necessary but not sufficient to cause periodontitis.⁴³ Various experiments have shown HBOT to have an abbreviated benefit on pocket reduction and bacterial elimination in patients with chronic periodontitis.⁴⁴ HBOT works by hindering the growth of subgingival obligate anaerobes and facultative anaerobes. By doing so, it advocates the healing of the infected periodontium.⁵

Dental implants

When a tooth becomes too badly damaged from trauma or decay to be properly repaired, it is often recommended to be extracted from the mouth. Dental implants have become an increasingly popular method of tooth replacement prior to extraction.⁴⁵ The implant is surgically placed into the mandible maxilla and retained during functional loading as a result of the ability for the bone to integrate with the implant as growth progresses.⁴⁶ Osseointegration is necessary for the implant to settle properly. For osseointegration to be successful, there must be relatively high biocompatibility between the material of the implant and the jaw bone, there must be adequate quality of bone tissue, proper surgical technique, and macro- and microstructure of the implant.⁴⁷ If the patient does not meet all of the following standards, HBOT is an advised treatment. HBOT prepares the bone and the adjacent tissue for implant retrieval.⁴⁸

Biofilms are commonly characterized as complex microbial communities that grow on various surfaces in nature.⁴⁹ The emergence of biofilms within the oral cavity commonly leads to an affluence of tissue loss and bone degradation. As a result, osseointegrated dental implants are frequently used with intention of restorative treatment of the oral cavity. These implants have the potential to provide new surfaces for the biofilm bac-



teria to form.⁵⁰ The resulting infections are difficult to treat with antibiotics. HBOT is commonly known to be a safe and effective means of treatment. A study done in 2012 exclaimed that the administration of high concentrations of oxygen therapy has a direct correlation to the growth of healthier tissue and higher affinity and implant-bone integration.⁵¹ However, there are minimal results leading to the necessity of HBOT prior to the placement of implants, only stating its effectiveness after the placement. A 15-year study conducted by Granstrom and colleagues concluded a 13.5% implant failure rate in non-irradiated patients and 53.7% in irradiated patients and 8.1% in irradiated patients receiving HBOT.⁵²

Oral submucous fibrosis

Oral submucous fibrosis is a constant debilitating disease as a result of juxta epithelial fibrosis of the oral cavity. Although success of treatment is rare, HBOT is commonly executed. This requires the patient to inhale 100% oxygen at increased atmospheric pressure often ranging between 2.0 and 2.5 atm (1 atm = 101.325 kPa) for 60–120 seconds. HBOT works to increase oxygen tension and flow to impaired tissue. HBOT also has the ability to prevent inflammation which helps expedite the healing process.⁵³

Mandible reconstruction

Oromandibular reconstruction is an extensive surgery with great benefits when completed successfully. The principle motive is to improve both function and aesthetic, when necessary. Surgeons manipulate the autogenous bone grafts to provide a substantial arch to articulate with the upper jaw, restoring swallowing speech, mastication and esthetics.⁵⁴ As procedures progress in difficulty, the probability of complications heightens. An 84-year-old woman was initially diagnosed with mucosal carcinoma of the right oral cavity. During reconstruction after segmental excision of the mandible, a titanium plate was selected based on several risk factors. After the operation, the plate became exposed at the center of the chin. After various other solutions were tested, it can be concluded that HBOT was the only auspicious solution. HBOT leads to epithelization of the wound.⁵⁵

POTENTIAL COMPLICATIONS

The most general complication faced from HBOT is barotrauma. Barotrauma is injury to your body because of barometric changes or significant adjustment in water pressure. The injury specifically targets the middle ear and sinuses because of the difference in pressure between the exterior and tympanic membrane. These symptoms include but are not limited to, ear pain, dizziness and muffled hearing. If adjustments are not made to the pressure, middle ear effusions, rupture of the tympanic membrane and sinus complications arise.⁵⁶ Due to the intimate connection between the teeth and the sinuses, dentists often encounter physiological and pathological phenomena resulting from the drastic increase in altitude.⁵⁷

Ontological complications, ocular or contraindications, osteogenesis, maxillary osteomyelitis, salivary gland function, and irritated oral mucosa will be further discussed.

Sinus complications

The human body anatomy renders an intimate relationship between the teeth and the sinus cavity. When there is pressure within the sinus cavity, there is potential for it to travel to the roots of the top of your teeth, specifically within the isolated upper teeth and back molars.⁵⁸ Specifically, the relationship of the maxillary posterior teeth with the sinus floor and buccal cortex. It has been proven through rigorous research that distance from root apex to the sinus floor increases with increased age of the patient. On the contrary, the palatal roots of maxillary first molars exhibited the highest incidence as well as the greatest mean length (1.96 mm) of protrusion into the maxillary sinus.⁵⁹

In consonance with Boyle's law, a significant modification in environmental pressure results in an inverse change in volume, thus leading to significant effect on the sinus cavity. Under systematic circumstances, the Eustachian tube within the ear must be open to eliminate the pressure difference between the internal and ambient environments. When the Eustachian tube is blocked, the sinus ostia is indirectly blocked. When the pressure change exceeds this capacity, sinus barotrauma transpires. If succumbs to carbon monoxide poisoning during HBOT, the rate of sinus abnormalities of barotrauma is 66.3%. It is important to air on the side of caution for the patients with history of sinusitis, otitis media and or upper respiratory infections as they tend to have a higher frequency of sinus barotrauma. The sinus cavities cooperate with the nasal cavities through ostia and a long duct in the sinuses. When the opening in the sinus ostium that connects the nasal cavity and the sinus is blocked, the pressure is no longer equally shared between them. As the ambient pressure is increased, it is transmitted through the sinus wall and often leads to vascular congestion and edema of the sinus mucosa. If the elastic limit of the sinus mucosa is surpassed, hemorrhage will occur.³⁷

Table 2: Sinus complications and hyperbaric oxygen therapy

Abnormality	Barotrauma group (n = 80)	Control group (n = 88)
Maxillary sinuses	35(43.8)	35(39.8)
Ethmoidal sinuses	34(42.5)	27(30.7)
Sphenoid sinus	20(25.0)	10(11.4)
Frontal sinuses	8(10.0)	6(6.8)

Note: Data were expressed as number (percent). Data were from Wang et al.⁶⁰

Otolological complications

A study done in 2015 by students at the Tokyo Medical and Dental University, Japan states the complications with HBOT within the department of otolaryngology. Otolology is a branch of medicine which studies normal and pathological anatomy and physiology of the ear as well as their diseases, diagnosis and treatment.⁵³ The complications assessed as a result of HBOT were otalgia, ear fullness, hearing loss and tinnitus.⁶¹ In conclusion, it is essential for physicians to be attentive to both middle and inner ear barotrauma as probable complications following HBOT.⁶¹ The interest within otology complications



in this article is undeviatingly relevant to the location of the sinus to the oral cavity. The thin floor of the main sinus can be found directly above the roots of the teeth towards the rear end of the oral cavity.⁶² Damage to the sinus cavity can result in damage roots of the oral cavity as they are so closely located. Damage to the roots often require extensive dental procedures such as extractions, root canals and periodontal surgeries. The amputation of the pulp as a result of infection and decay within the enamel and dentin require extensive treatment and can be harmful to the rest of the oral cavity if not properly treated in a timely manner.⁶³

Ocular complications and contraindications

HBOT increases the concentration of reactive oxygen species in blood and tissue as a result of the increase in oxygen pressure. This is often beneficial concerning various diseases but may result in ocular complications as a result. An abundance of reactive oxygen species in tissues and or deficiencies in antioxidant activity are frequent contributions to specific ocular complications such as cataracts.⁶⁴ Cataracts are presented as opacification of the customary crystalline lens.⁶⁵ The high concentration of reactive oxygen species and deficiencies in antioxidant activities have the ability to contribute to keratoconus, a disorder of the eye distinguished by the dissipation and prominence of the cornea.⁶⁶ Complications such as keratoconus are commonly aggravated by exposure to additional reactive oxygen species throughout the exploitation of HBOT. The retina is extremely prone to oxidative damage as elucidated by macular degeneration and cataract as a result of the retina's susceptibility to oxidative stress. For instance, macular degeneration commonly comprises of oxidative stress and death of the retinal pigment epithelial cells as a result of increasing age. HBOT has the potential to exaggerate these processes resulting in various complications subsiding in the retina.⁶⁴

For example, under normal conditions age-related macular degeneration involves oxidative stress and death of the retinal pigment epithelial cells. HBOT may exacerbate these processes. In addition to cataract, age-related macular degeneration and keratoconus, there may be other ocular diseases for which exposure to HBOT-related oxidative stress may be significantly adverse.

Periosteal distraction osteogenesis

The restoration of bone loss and complications that emerge as a result are often convoluted and potentially improbable. As a result, a new technology in which consists of creating an artificial space between the bone surface and the periosteum to generate new bone by gradually expanding the periosteum without following through with a corticotomy. This treatment process effectively prevents the potential complications as a result of the body's immune system but also decrease the potential of an inadequate donor.⁶⁷ A study done in 2014 on rabbits indicated a positive relationship between periosteal distraction osteogenesis and HBOT. Mature mammals treated with HBOT for 8 weeks saw that the quality and quantity of the newly formed bone were improved.⁶⁸

Maxillary osteomyelitis associated with osteopetrosis

Osteopetrosis is an infrequent condition which prevents growth of bone density and leads to deficient bone remodeling. The severity of the conditions range from neonatal on-set with life-threatening complications such as bone marrow failure.⁶⁹ The most common is characterized by fractures, short stature, compressive neuropathies, hypocalcemia and attendant tetanic seizures. Specific to maxillary, it appears as a critical increase in bone density, as a result of defection of the osteoclasts within the body.⁷⁰

The treatment of maxillary osteomyelitis in patients with autosomal dominant osteopetrosis type II is unfeasible with merely antibiotics such as amoxicillin and clavulanic acid.⁷¹ The use of HBOT has been found to be successful. HBOT is crucial for bone regeneration, as it allows for a significant inflation of angiogenesis. The development of angiogenesis signifies an increase in tissue growth. Although osteopetrosis specifically affects bone density, the increase in tissue regeneration has a positive effect on the maxillofacial region.⁷²

Salivary gland function

The development of salivary glands is carried out by branching morphogenesis. The goal of the salivary gland is to produce and effectively secrete saliva. The development requires adequate functioning and harmony among epithelial, mesenchymal, neuronal and endothelial cells. Tissue bioengineering and gene-and cell therapy are commonly the most productive way to regenerate these cells.⁷³ HBOT is necessary for hydroxylation of lysine and proline residues during collagen synthesis. This expedites cross linking and maturation of collagen which allows for vigorous healing, including but not excluded to the epithelial, mesenchymal, neuronal and endothelial cells.⁷⁴ The status of the salivary glands can be validated with the machinery best known as DW-MRI. It has the potential to check the physiological and functional changes proceeding hyperbaric oxygen therapy.⁷⁵

Irradiated oral mucosa microvessel density

Succeeding radiation therapy, it is common to see slight eradication of cell proliferation and microvascular tissue in the oral mucosa. At high concentrations of radiation therapy, protein cell DNA is damaged beyond repair which prevents the cells from dividing, thus it can no longer survive. In the human body, RAD51AP1 is imperative for homologous recombination as it highly cooperates with and stimulates the function of RAD51 and DMC1 recombinases.⁷⁶ Oral mucositis potentially results in an inflammatory response, repopulation, in fractionated radiotherapy protocols preceding and paralleling the epithelial changes, macrophages and fibroblasts.⁷⁷

Exfoliative oral cytology is commonly used as a diagnostic and prognostic methodology for overseeing patients battling oral cancer and potential malignant disorder.⁷⁸ When the body is inflamed, there appears to be a higher concentration of lymphocytes. A high concentration of lymphocytes typically means the body is fighting off an infection. It is also common for the epithelial cells to present an abnormal folding phenotype. After application of HBOT, the density of the blood vessels and area were increased almost immediately.

D2-40 positive lymphatic vessels were significantly increased in both the number and area within the sub-epithelial. There also appeared to be normal folding within the epithelial cells. The strongest results were obtained 6 months after the treatment of HBOT.⁷⁹

PLIABILITY OF HYPERBARIC OXYGEN THERAPY

HBOT can be manipulated and safely utilized under various conditions. It can overcome the complication of medically-ventilated patients and provide very efficient treatments.

Acute respiratory distress syndrome

Acute respiratory distress syndrome is commonly found to be the basis of the necessity of ventilation. Acute respiratory distress syndrome results from a highly concentrated protein edema that engenders severe hypoxemia and incapacitated carbon dioxide excretion. Sepsis, pneumonia, aspiration of gastric contents, and a wide array of major traumas are often associated with the development of this condition. The neutrophil-dependent and platelet-dependent damage to the endothelial and epithelial barriers of the lung primarily cause lung injury. This injury of the lung epithelial barrier prevents removal of alveolar edema fluid and deprives the lung of adequate quantities of surfactant which delays resolution.⁸⁰ HBOT is a safe method for patients who require mechanical ventilation. The only potential complication is regarding sedation. Sedation must be perfect prior to the treatment; otherwise patients may face ventilator asynchrony.⁸¹ Patient-ventilator asynchrony is the incongruous between neural inspiratory and mechanical inspiratory time. Modifications in timing, respiratory drive, respiratory muscle pressure and respiratory system mechanics influence the interaction between the patient and the ventilator.⁸²

Irradiated maxillofacial dental implants

Dental implants are artificial tooth roots made of titanium, which have the capabilities of holding various types of artificial teeth, such as crowns, bridges and dentures. These implants are anchored in the jawbone, where the bone tissue integrates with the implant to form a stable foundation for the artificial tooth.⁸³ If the bone tissue does not integrate with the titanium implant, the implant is rejected and causes further complications. Implant rejection may be caused by the long-term effects on reduced vascularization comprising the implantation site. Within every natural tooth, there is an endodontium. The endodontium is in the center of the tooth, highly vascularized and surrounded by rigid dentin walls and made up of living connective tissue and cells called odontoblasts. The pulp vascular system is established by vasculogenesis during embryonic development, sprouting angiogenesis is the predominant process during regeneration and therapeutic processes.⁸⁴ The high vascularity constitutes the pulp as an effective way to supply nutrients and remove waste. It is also responsible for regeneration and tooth transplantation.⁸⁵

HBOT can improve the tissue vascularity, thus increasing the implant survival rate by enhancing osteointegration within the patients. The graph below shows the significant difference regarding the implant failure rate between those treated with

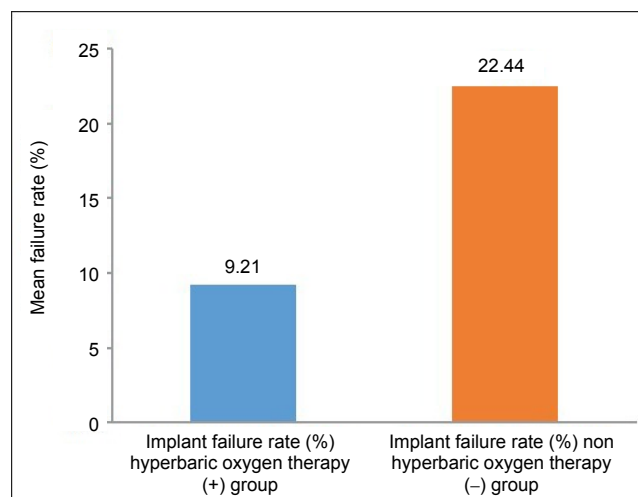


Figure 1: Effect of hyperbaric oxygen therapy on implant failure rate.

Note: Data were from Lynch and Deaton.⁵¹

and without HBOT. There is clear evidence that HBOT has a positive effect on implant osteointegration.⁸⁶

Aside from lack of vascularity with the oral cavity, implants can be rejected from inflammation caused by oral microflora thus leading to peri-implantitis.⁸⁷ Peri-implantitis is the destructive inflammatory process affecting the soft and hard tissues surrounding dental implants. The site-specific infectious diseases causes an inflammatory response in the soft tissue and leads to severe bone loss around the titanium implant.⁸⁸

Non-irradiated bone grafting

Bone grafting is a surgical procedure that uses transplanted bone to repair and rebuild diseased or damaged bones. Materials for the bone graft can be artificial, natural, synthetic, or even taken from the patient's own body. The purpose of bone grafting is to facilitate healing and promote osseointegration of the titanium implant where there is not a sufficient amount of bone present in the targeted area.⁸⁹ HBOT works in conjunction with other treatments to heal bone grafting as it has been proven to expedite the healing process.⁹⁰ It also has the ability to facilitate the functional recovery of patients and to reduce the postoperative complications when deactivated and washed thoroughly with saline.

CONCLUSION

HBOT is an effective treatment in dental medicine as it facilitates the healing process and expedites the recovery of the patient. Despite the potential complications that may arise, it has various benefits. As previously stated, HBOT often works well in conjunction with other treatments.⁹¹

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Author contributions

Study design, concept and definition: KR, SP, JG, YS, IR, GJ, NLS, SAK. All authors read and approved the final version of the paper for publication.



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