# Hyperbaric Oxygen Therapy for Wound Dehiscence After Intraoral Bone Grafting in the Nonirradiated Patient: A Case Series

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**Purpose:** In maxillofacial surgery, hyperbaric oxygen treatment is used almost exclusively as adjunctive therapy for osteoradionecrosis of the mandible in irradiated patients. It also is used to prevent the occurrence of osteoradionecrosis in the irradiated patient when dental surgery is indicated. Theoretically, hyperbaric oxygen therapy should benefit the nonirradiated patient in maxillofacial surgery (eg, patients with persistent intraoral wound dehiscences after bone grafting).

**Materials and Methods:** Six nonirradiated patients underwent hyperbaric oxygen therapy because of compromised wound healing after intraoral bone grafting of the maxilla as a preimplant procedure. All patients were treated 7 to 26 times with hyperbaric oxygen therapy at 2.5 ATA.

**Results:** All patients healed uneventfully. In retrospect, almost all patients had a history of chronic maxillary sinusitis or trauma to the operated area.

**Conclusion:** Hyperbaric oxygen therapy seems to be an effective adjunctive therapy in the treatment of nonirradiated patients with compromised intraoral maxillary bone graft healing. Chronic maxillary sinus problems or a history of trauma could predispose to wound dehiscence after bone grafting.

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Hyperbaric oxygen therapy (HBOT) is used for different clinical problems, such as carbon monoxide poisoning,[1] diabetic foot ulcers,[2] gas gangrene,[3] and ischemic wounds. For ischemic wounds, it is used as treatment or before skin grafting and to prevent or treat ischemic flaps.[4] HBOT also is used as a treatment for late radiation tissue injury in various parts of the body.[5,6]

In oral and maxillofacial surgery, HBOT is indicated as treatment for late radiation tissue injury osteoradionecrosis.[5] It also is used as a prophylactic measure when postirradiation dental care involving trauma to tissue is necessary.[5,7]

HBOT is used for a wide range of indications because of its physiologic effect. The therapy involves therapeutic administration of 100% oxygen at environmental pressures of 2.5 ATA. In this way, the partial pressure of oxygen is greatly increased to the lungs, blood, and tissues. The intermittent application stimulates new vascularization in the affected tissue, as observed in oral mucosal flaps in rabbits.[8] Also, by increasing oxygen levels,

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white blood cell counts and fibroblast function improve.[9]

Through these mechanisms, HBOT could be beneficial in nonirradiated patients with intraoral compromised wound healing. This report presents a case series of 6 nonirradiated patients with intraoral compromised wound healing after maxillary bone grafting procedures for dental implants that was successfully treated with hyperbaric oxygen.

## Report of Cases

From 2010 to 2016, 6 patients were referred to the Institute of Hyperbaric Medicine (Hoogeveen, The Netherlands). All patients were indicated for treatment with dental implants in the maxilla, but bone grafting was necessary to obtain sufficient maxillary bone volume (Table 1). Five patients were edentulous and needed dental implants because of poor denture retention from resorption of the maxilla. When chronic sinusitis was present before augmentation, a structural sinus clearance was performed by the ear, nose, and throat specialist. When computed tomography showed a healthy sinus, maxillary sinus floor elevation surgery and buccal plating was performed with anterior iliac crest bone grafts.[10] One dentate patient needed only buccal plating of a deficient alveolar process at the location of the left upper central incisor. In this case, retromolar bone and then calvarial bone were used to reconstruct the deficient alveolar process (Fig 1).[11]

In the first weeks after surgery, all patients presented with persistent intraoral mucosal dehiscences that would not heal after surgical debridement, broad-spectrum antibiotics, and (repeated) meticulous surgical closure by advancing the mucosa (advancement flap). A persistent open wound would prevent vascular ingrowth in the bone graft and serve as a "porte d'entrée" for bacteria. As a "last resort" to close the wound, patients were referred to the Institute of Hyperbaric Medicine. The time from bone graft surgery to the start of the HBOT was 10 to 11 days. The 5 edentulous patients were referred to the hyperbaric facility after 10 days when no signs of wound healing were present, despite the efforts described earlier (Fig 2). The dentate patient (patient 6) was referred after 11 days of wound dehiscence (Fig 1).

HBOT included sessions of 90 minutes in a multiplace chamber pressurized at 2.5 ATA in which patients breathed 100% oxygen, except for 3 blocks of 5 minutes when they breathed ambient air to prevent oxygen toxicity. HBOT was scheduled 5 days a week until complete wound healing was achieved. The number of sessions varied from 7 to 26 (mean, 13 sessions).

During treatment, wound dehiscences resolved by secondary epithelialization. All patients healed completely and uneventfully. After complete bone graft healing, dental implants were placed after 3 months and retrieved and loaded another 3 months later. All 21 dental implants were successfully osseointegrated.

## Discussion

This case series shows the beneficial effect of hyperbaric oxygen in nonirradiated patients with nonhealing mucosal defects after bone grafting in oral and maxillofacial surgery.

A nonhealing wound is defined as a wound that fails to heal within a reasonable period by the use of conventional medical or surgical techniques. Nonhealing wounds are the result of an impairment of at least 1 healing process. The most important factors resulting in impaired healing are ischemia and infection.[12] Hyperbaric oxygen influences ischemia and infection by increasing the oxygen tension between the underlying blood vessels and the hypoxic wound or recipient site during therapeutic sessions. This higher oxygen tension stimulates angiogenesis.[9] Subsequently, more oxygenated blood can reach the wound, thereby maintaining the integrity of the healed tissue after the therapy sessions.[8,13] Bayati el al[14] reported a marked increase in the area of myocutaneous flap survival through improved vascularity using hyperbaric oxygen. Perrins[15] conducted a randomized controlled trial and found an overall 29% improvement in skin graft survival in the group treated with hyperbaric oxygen. The high oxygen tension during the sessions also counteracts the increased oxygen consumption from infection.[12] It stimulates host defenses against infections and potentiates the effect of certain antibiotics.[16]

The current literature does not contain other human studies on the intraoral effect of hyperbaric oxygen in the nonirradiated patient, but there is an animal study addressing the positive effect on intraoral wound healing. Helmers et al[8] conducted a study in rabbits in which they suggested that hyperbaric oxygen could stimulate wound vascular regeneration in healing keratinized oral mucosal flaps.

In general, mucosal wounds tend to heal fast and with minimal scar formation compared with dermal wounds. This is due to an accelerated decrease of the inflammatory phase, fewer immune mediators, less blood vessel formation, more bone marrow–derived cells, and an accelerated re-epithelialization and proliferation of fibroblasts in the mucosa.[17] Despite this better healing capacity of the mucosa compared with skin, compromised healing of the intraoral cavity does occur as reported in this series.

The question arises as to why these wound dehiscences occurred. Wound healing is a delicate balanced process with many factors that can interfere with the

**Table 1. CHARACTERISTICS OF TREATED PATIENTS DESCRIBED IN THIS CASE SERIES**

| Patient Number | Age (yr) | Gender | Surgery | Course | Sessions, n | Result | Relevant Medical History |
|---|---|---|---|---|---|---|---|
| 1 | 74 | M | Bilateral sinus lift and buccal plating with anterior iliac crest bone graft (Fig 2) | 10 days postoperatively, the wound appeared necrotic and the bone graft was at risk (Fig 2); after debridement, HBOT was started | 10 | Healed | Chronic sinusitis |
| 2 | 59 | M | Bilateral sinus lift and buccal plating with anterior iliac crest bone graft | After 3 days, the mucosa became dehiscent; HBOT was started after 10 days | 15 | Healed | Le Fort I fracture, maxillary osteotomy |
| 3 | 40 | M | Bilateral sinus lift and buccal plating with anterior iliac crest bone graft | After 3 days, the mucosa became dehiscent and the bone graft was at risk; HBOT was started after 10 days | 10 | Healed | Le Fort I fracture |
| 4 | 71 | M | Bilateral sinus lift and buccal plating with anterior iliac crest bone graft | A few days later, the mucosa became dehiscent; HBOT was started | 9 | Healed | Midface fracture in childhood |
| 5 | 51 | M | Bilateral sinus lift and buccal plating with anterior iliac crest bone graft | Wound dehiscence of the maxilla followed; HBOT was started | 10 | Healed; hypertrophy of mucosa occurred and was corrected with coagulation | Maxillary sinusitis, surgical closure of antral perforation |
| 6 | 37 | M | Double plating of location of tooth 21 with calvarial bone (Fig 1) | After 5 days, the buccal advancement flap became dehiscent; unsuccessful closure with a partial-thickness palatal rotation flap followed; after 6 wk, a full-thickness palatal flap was used to cover the defect; 10 days later, the wound started to become dehiscent again (Fig 2); HBOT was started | 26 | Complete healing; 7 months afterwards, the dental implant was placed successfully | Missing tooth 21 after trauma (fall from stairs), 2 failed attempts to reconstruct location of tooth 21 with retromolar bone |

Abbreviations: F, female; HBOT, hyperbaric oxygen therapy; M, male.

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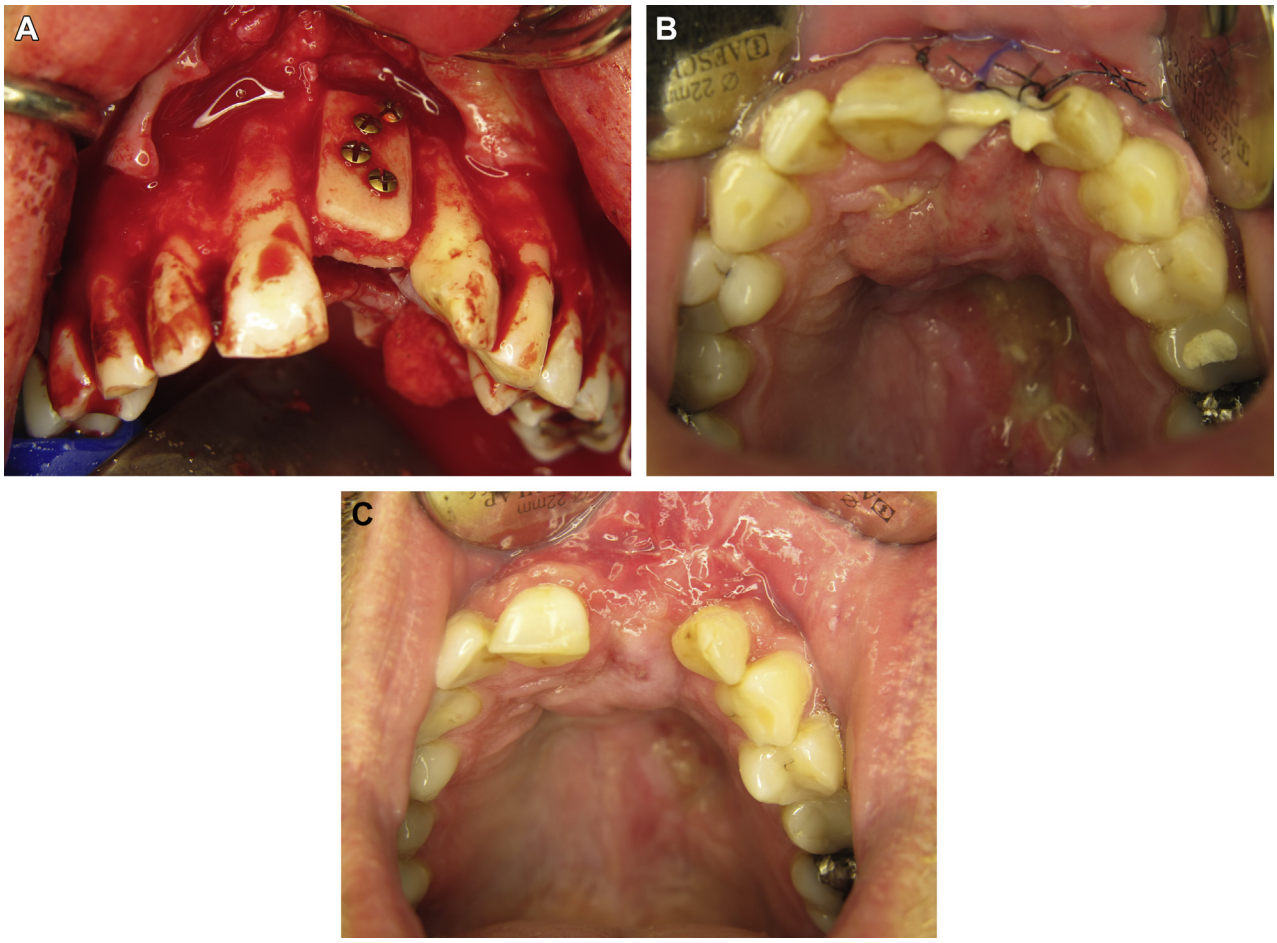


**FIGURE 1.** *A*, Augmentation of the alveolar process with calvarial bone. Primary closure with a buccal advancement flap. *B*, Situation after 3 failed attempts to close the wound during the course of 3 months (buccal flap, partial palatal flap, and full-thickness palatal flap). This image was taken 11 days after placement of the full-thickness palatal flap. Wound-healing disturbance is clearly visible. *C*, Complete healing after hyperbaric oxygen therapy.

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reparative tissue response to acute traumatic ischemia and chronic hypoxia. A very important factor in wound dehiscence is the surgical technique. After bone grafting, a tensionless closure of the oral mucosa is mandatory to prevent dehiscences. All patients were operated on by 2 experienced maxillofacial surgeons, and the subsequent procedures were uneventful. Also, none of the patients used a medication that could compromise wound healing. All patients were nonsmokers. Postoperatively, all patients received broad-spectrum antibiotics to prevent infection.

However, in retrospect, almost all patients in this series had a medical history of (chronic) sinusitis or trauma to the maxilla. Therefore, the question arises as to whether trauma of the maxilla or chronic sinusitis might be related to (sub)ischemic mucosa that might manifest as a nonhealing mucosal defect after surgery.

To the authors' knowledge, this is the first case series describing the beneficial aspect of HBOT for persistent wound dehiscences after bone grafting in the maxilla. Many questions remain to be answered, such as when HBOT should be started, if at all, and how long it should be continued. Also, the effect on the bone quality of the graft and on the survival of dental implants is not clear.

In oral and maxillofacial surgery, HBOT is almost exclusively used for prevention and as adjunctive therapy to osteoradionecrosis of the mandible in irradiated patients. These patients have sub-ischemic tissues in the irradiated area and therefore could develop wound-healing difficulties after surgery or tooth extractions. Thorn et al[18] measured the effect of hyperbaric oxygen on transmucosal oxygen tension in irradiated human oral mucosa. During HBOT, the transmucosal tension increased considerably after 5 sessions. After 30 sessions, the mean increases were 50 to 86% of the transmucosal oxygen tension of normal healthy gingiva. They concluded that patients with sub-ischemic tissues could benefit from HBOT.

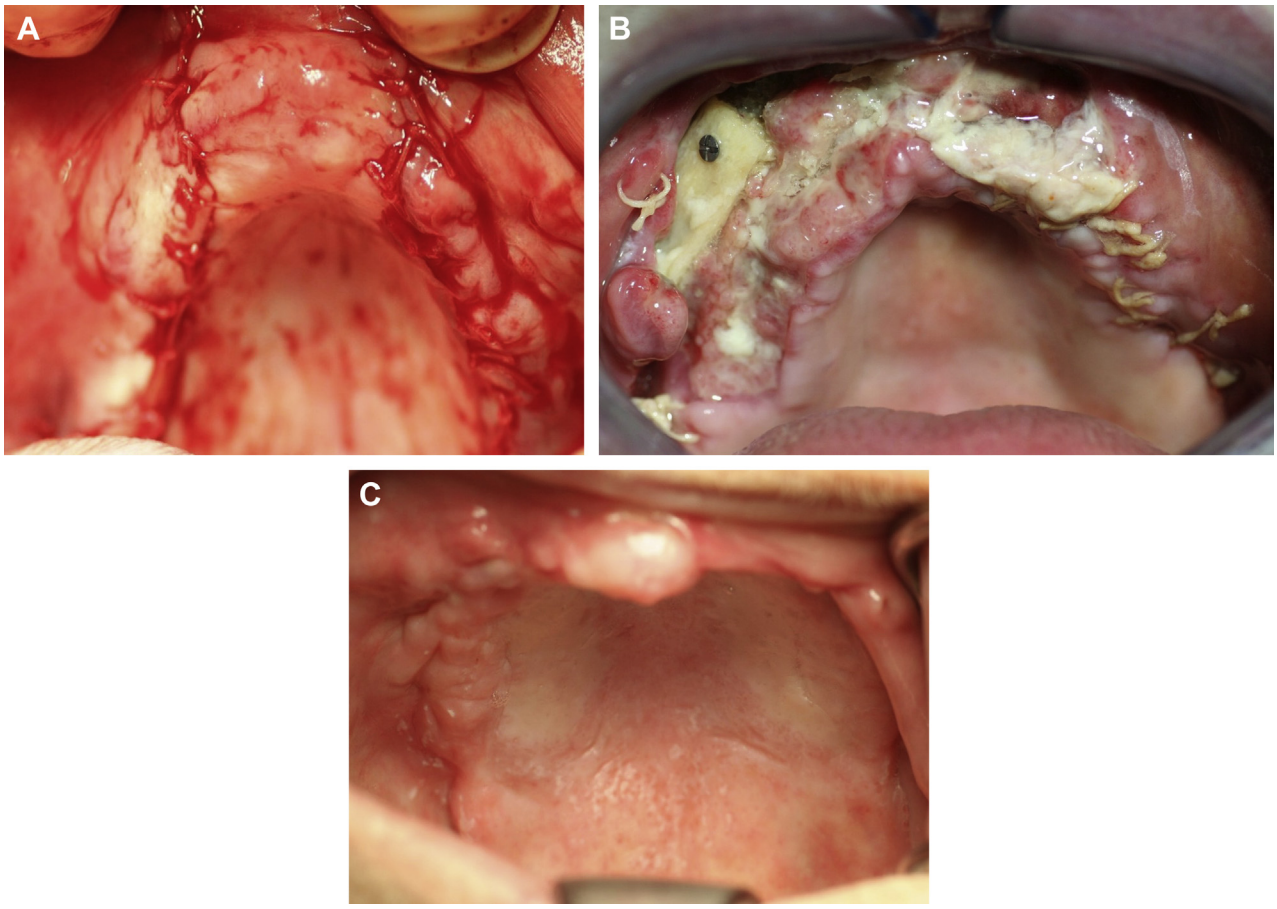


**FIGURE 2.** *A,* Surgical closure after bilateral maxillary sinus floor elevation and buccal plating with anterior iliac crest bone. Vascular normal aspect of the mucosa. *B,* Wound dehiscence after 10 days. Part of the bone graft is visible. *C,* Ten 10 days after hyperbaric oxygen therapy, the wound has healed successfully.

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Also, the study of Svalestad et al[19] concluded that not only oxygenation but also vascular capacity in irradiated gingival mucosa is increased by HBOT.

When intraoral wounds, despite using conventional medical or surgical techniques, fail to heal, HBOT should be considered. According to the present case series, the viability of transplanted tissue and wound healing could be at risk when chronic sinusitis or maxillary trauma precedes maxillary bone grafting procedures. In these cases, adjunctive HBOT could be helpful.

In conclusion, HBOT could be an effective adjunctive therapy to the treatment of patients with persistent wound dehiscence related to bone grafting procedures of the maxilla. A history of maxillary trauma or chronic maxillary sinusitis could predispose to such healing disturbances in these patients.

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