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REVIEW ARTICLE

The role, safety, and efficacy of hyperbaric oxygen therapy in aesthetic practice—An evidence-based review

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Abstract

Background: Hyperbaric oxygen therapy (HBOT) involves patients breathing 100% oxygen in a pressurized chamber, above 1 atmosphere. Many centers are now promoting the use of HBOT for skin rejuvenation. However, the current indications for HBOT do not encompass aesthetic applications.

Aim: The aim of this evidence-based review was to assess the existing literature regarding the utilization of HBOT in medical aesthetics and rejuvenation, evaluate its effectiveness and safety, and conduct a cost analysis.

Materials and Methods: PubMed Interface, Cochrane Library, Google Scholar, and Embase searches were carried out. The Best Bets methodology was used, and the risk of bias was appraised using the Quality Assessment Tool for Quantitative Studies.

Results and Main Findings: This review included a total of 17 human studies with a total of 766 participants. Three studies were classified as level II evidence, three studies were of level III evidence, and 11 were of level IV evidence. All the included studies were judged at high risk of bias. The most relevant findings supported by level II evidence were that HBOT decreased the shedding rate post-FUE hair transplant ($27.6 \pm 2.6\%$ vs. $69.1 \pm 2.4\%$) but this did not affect the final outcome between HBOT ($96.9 \pm 0.5\%$) and the control ($93.8 \pm 0.6\%$). Moreover, level III evidence demonstrated that following HBOT, there was a significant increase in elastic fiber length ($p \leq 0.0001$, effect size = 2.71) and a significant decrease in fiber fragmentation ($p = 0.012$). There was also a significant increase in collagen fiber density following HBOT ($p = 0.0001$, effect size = 1.10). However, there was no significant effect of antioxidant vitamins A, C, and E with HBOT. The inflammatory response significantly decreased after 7 days of HBOT with a decreased expression of IL-12p40, MIP-1β, and PDGF-BB and a higher expression of IL-1Ra. Moreover, HBOT was used prophylactically prior to abdominoplasty to decrease the risk of complications. In this study, complications were decreased from 32.6% (89 patients) to 8.4% (7 patients) with a $p < 0.001$, and in a multivariate analysis, preoperative HBOT was an independent protective factor against postoperative complications ($p < 0.001$).

Conclusion and Recommendations: There is conflicting evidence on how the method of action of HBOT can have a beneficiary effect in aesthetic and whether the treatment is justifiable. To our knowledge, this is the first comprehensive review discussing the available evidence regarding the use of HBOT in many aesthetic clinical scenarios, including preventive, medical, and surgical settings. However, randomized clinical trials with longer follow-up and better patient selection are needed to be able to generate a reliable conclusion.

KEYWORDS
aesthetics, HBOT, hyperbaric, oxygen therapy, rejuvenation

1 | INTRODUCTION

Hyperbaric oxygen therapy (HBOT) involves patients breathing 100% oxygen in a pressurized chamber leading to an increased dissolved oxygen contact to that above physiological level.[1] The majority of evidence showed that this pressure should be >1 atmosphere (atm).[2] Instead, Gold et al.[3] acknowledged that the pressure should be more than 1.4 atm., while Yoshinoya et al.[4] stated that this pressure should be higher than twofold atmospheric pressure, which is at least 2 atm.

HBOT was originally mentioned back in 1662, when it was used by the British clergyman, Nathaniel Henshaw, to treat diverse long-term conditions. He had constructed an airtight chamber where the atmosphere could be compressed using bellows and valves, called a "Domicilium." Later on, in 1837, it was used to treat miners with decompression sickness.

The first ever HBOT chamber in the American Continent was built in New York in 1861. However, it took almost another 60 years for the "steel ball hospital" to be built in Kansas and become one of the most iconic healthcare establishments back in its time. It consisted of a five-storey spherical building, which was built by Cunningham and accommodated up to 40 patients at a time.

The use of HBOT mainly gathered momentum in 1937, when Behnke and Shaw used it to treat decompression sickness, and already by the late 50s, it was widely used as a treatment modality for various medical conditions. A breakthrough year was 1955, when Churchill-Davidson et al. utilized hyperbaric oxygen treatment for addressing the side effects of radiotherapy in cancer patients. Ite Boerema, better known as the father of modern hyperbaric medicine, first published back in 1956, implementing intraoperatively HBOT during cardiac surgery, followed by Kulonen in 1968, who reported its use in dealing with chronic wounds.[5]

The Undersea and Hyperbaric Medical Society (UHMS) was established in 1967 to create regulations, training, and certifications. It acts as the primary scientific body for HBOT in the USA. One of its roles was to come up with a list of indications for the use of HBOT.[6]

Many centers worldwide are currently promoting the use of HBOT to rejuvenate skin and slow down the aging process. However, the Tenth European Consensus Conference on Hyperbaric Medicine, which was held in April 2016, did not specifically include aesthetics as being one of the indications for HBOT. However, this paper listed some indications, such as sudden deafness, central retinal artery occlusion, surgery and implant in irradiated tissue, and selected non-healing wounds secondary to systemic processes can be considered in aesthetics as shown in Table 1.[7]

This review aimed to explore all the studies relevant to HBOT in aesthetics, investigate its safety and efficacy, and provide an analysis of the costs related to buying a hyperbaric chamber and sustaining a profitable business.

2 | MATERIALS AND METHODS

An evidence-based review was done using the Best Bets Methodology based on the three-part research question as shown in Table 2.[8]

TABLE 1 Tenth European Consensus Conference list of aesthetic indications for HBOT.[7]

Condition	Level of evidence (based on GRADE system)	Agreement level strength of recommendation (consensus-based)
Sudden deafness	Level B	Strong agreement
Central retinal artery occlusion	Level C	Strong agreement
Surgery and implant in irradiated tissue (preventative treatment)	Level C	Agreement
Selected non-healing wounds secondary to systemic processes	Level C	Agreement

TABLE 2 Three-part research question.

Patient group	Healthy adults seeking aesthetic treatments
Intervention or defining question	HBOT
Relevant outcome	Indications, clinical, and participant-related outcomes, and adverse events to report efficacy and safety of HBOT, cost analysis

Medline searches via PubMed Interface, Cochrane Library, Google Scholar, and Embase were carried out as per Table 3.

Two independent reviewers (JP and HH) have searched the databases, and any disagreements on exclusion and inclusion criteria were resolved through discussion with a third reviewer (AMF). No filters were applied to the search and all the relevant human papers in the search were included in the review. Two reviewers (JP and HH) independently extracted data from the human studies only. The PRISMA flow diagram shown in Figure 1 is used to demonstrate the pathway taken to identify the studies for this review. Inclusion and exclusion criteria are shown in Table 4. The risk of bias was appraised in the 17 Human studies using the "Quality Assessment Tool for Quantitative Studies" by two independent reviewers (JP and HH). Any difference in opinion was discussed with a third reviewer (AMF).[9]

The Oxford classification was used to evaluate the level of evidence of the studies relevant to the research question.[10] In order to carry out a cost analysis, multiple clinics and medical centers providing HBOT treatments and hyperbaric chamber sellers were contacted. The approximate number of treatments that need to be performed for a possible business to be profitable were worked out.

3 | RESULTS

This section highlights the main topics that emerged from the existing literature within the realm of HBOT in the world of aesthetics. Studies are classified into six domains, depending on the area in aesthetics that the authors of the papers researched: Prevention of skin aging, Rejuvenation, Management of Complications in Aesthetic Medicine, Management of Complications in Aesthetic Surgery, Hypertrophic and Keloid Scarring, and Hair Transplantation. A summary of the papers included is shown in Table 5 according to the Best Bets protocol.

The most interesting results were that following HBOT, there was a significant increase in elastic fiber length ($p \leq 0.0001$, effect size = 2.71) and a significant decrease in fiber fragmentation ($p = 0.012$). There was also a significant increase in collagen fiber density following HBOT ($p = 0.0001$, effect size 1.10).[11] However, there was no significant effect of antioxidant vitamins A, C, and E with HBOT.[12] The inflammatory response significantly improved after 7 days of HBOT with a decreased expression of IL-12p40, MIP-1β, and PDGF-BB and a higher expression of IL-1Ra.[13] HBOT was also used prophylactically prior to abdominoplasty to decrease the risk of complications. In this study, complications were reduced from 32.6% (89 patients) to 8.4% (7 patients) with a $p < 0.001$ and in a multivariate analysis. Preoperative HBOT was an independent protective factor against postoperative complications ($p < 0.001$).[14] HBOT also decreased the shedding rate post-FUE hair transplant ($27.6 \pm 2.6\%$ vs. $69.1 \pm 2.4\%$) but this did not affect the final outcome between HBOT ($96.9 \pm 0.5\%$) and the control ($93.8 \pm 0.6\%$).[15]

The geographical distribution of the publications per country as well as the year of publication is summarized in Figure 2.

The risk of bias was appraised in the 17 Human studies using the "Quality Assessment Tool for Quantitative Studies" as per Table 6. This tool was developed in Canada by the public health sector to test and provide evidence to support public health inventions and researches. This can be used in a wide range of health-related topics. Table 6 provides the score for each section of the quality assessment tool and the overall global rating of the bias. The assessment for each study is included in the supplemental material.[9]

4 | DISCUSSION

The authors were aware of only one previous review by Asadamongkol et al (2014) regarding the use of HBOT in aesthetics. However, eligibility criteria within the current study were broader and more inclusive; for example, Asadamongkol et al limited their review to skin rejuvenation and treatment of photoaging only. Moreover, the authors mainly described the mechanisms of action and concluded that the evidence was conflicting mostly due to issues of whether the suppression of HIF-1a protein can inhibit angiogenesis and if this was actually beneficial or not. The need for results refinement highlights the importance of the broad scope of the current review.[16]

Therefore, we have delved into the best available evidence on the use of HBOT in many aesthetic clinical settings, extending the findings to both medical and surgical fields. Thus, we have followed the best BETs methodology and the studies included in this review are very different. Noteworthy that the Tenth European Consensus Conference on Hyperbaric Medicine does not mention aesthetics specifically as being one of the indications for HBOT. Nevertheless, some of the current indications may also be applied in aesthetics. For example, sudden deafness could occur following filler injection as per the case report by Henderson et al. Moreover, central retinal artery occlusion may arise following the injection of fillers and can be confirmed with imaging and fundoscopy. HBOT can be considered a prophylactic treatment to prevent skin necrosis when implants are used in irradiated tissues for

TABLE 3 Medline searches.

PubMed	A PubMed advanced search including all the below MeSH terms was done Search: ("hyperbaric oxygen therapy") AND (aesthetics) "hyperbaric oxygen therapy"[All Fields] AND ("aesthetical"[All Fields] OR "esthetically"[All Fields] OR "esthetical"[All Fields] OR "esthetically"[All Fields] OR "aesthetics"[MeSH Terms] OR "aesthetics"[All Fields] OR "aesthetic"[All Fields] OR "aesthetics"[All Fields] OR "aesthetic"[All Fields])
Cochrane Library	A Cochrane Library search with the term "hyperbaric oxygen therapy" was done
Embase and Google Scholar	An Embase and Google Scholar search with the terms "hyperbaric oxygen therapy" AND "aesthetics" was carried out

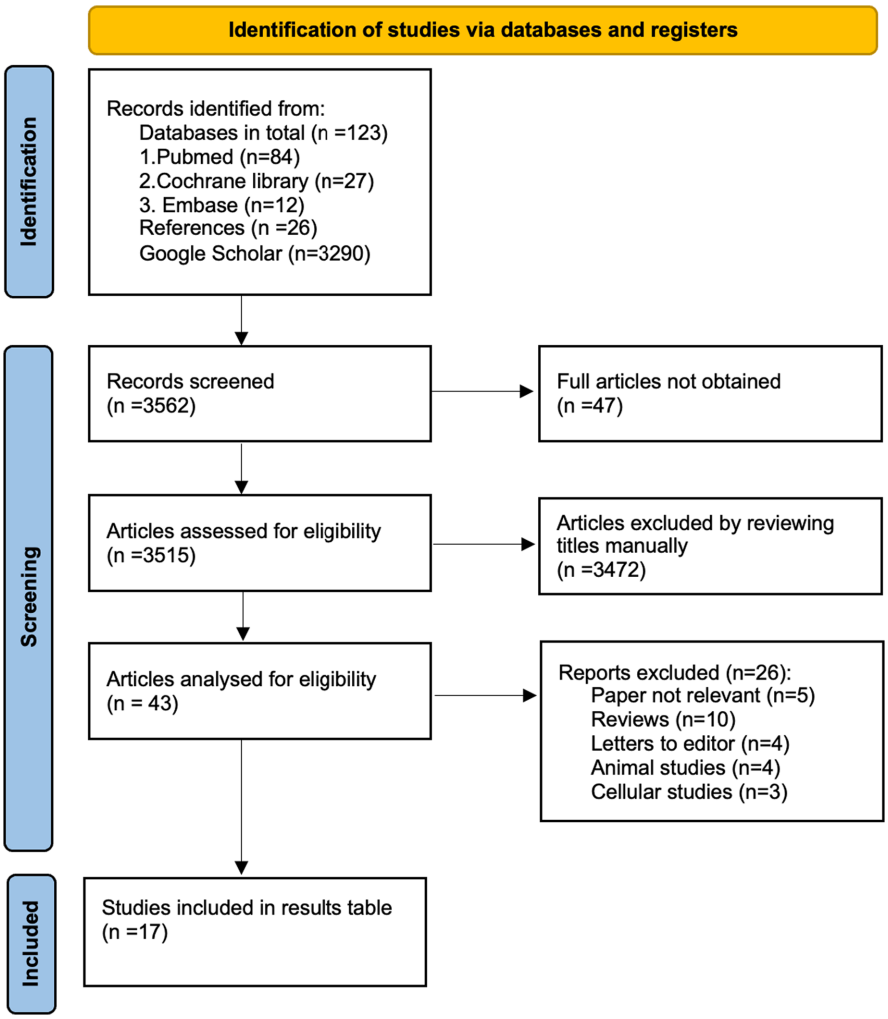

FIGURE 1 PRISMA flow chart highlighting the pathway used to identify the relevant studies to be included in the results table.

cosmetic procedures. Filler injections and aesthetic surgery can lead to non-healing wounds from systemic processes, which may also benefit from HBOT.

Although we need to exercise caution in interpreting the findings because of the small number of studies, they have found other specific aesthetic clinical scenarios where HBOT has been proposed. There were 15 patients from case reports and case series where HBOT was employed to limit skin damage and scarring following a vascular occlusion from fillers, including hyaluronic acid fillers, calcium hydroxyapatite, and a placental extract filler. It is to be noted that 12 of these 15 patients (80%) were below the age of 45 years and did not have any ongoing systemic processes. In addition, in 34 patients, HBOT was employed following hair transplantation; in 295 patients, this was utilized for keloid scarring; 83

Inclusion criteria	Exclusion criteria
Human studies related to HBOT and aesthetics.	All studies not written in the English language
Studies in the English language	Relevant studies that did not offer a free full text with the subscriptions of the authors
	Animal and cellular studies
	Reviews
	Letters to the editor

TABLE 4 Inclusion and exclusion criteria for the studies included in the results table.

patients had HBOT prophylactically before abdominoplasty; in 13 subjects, it was used for investigating rejuvenation purposes, and in 16 individuals, it was carried out to study antioxidant activity. Notably, in 453 patients (59%), HBOT was used beyond the indications supported by the Tenth European Consensus Conference. The findings of this evidence-based review are based on 17 human studies with a total of 766 participants. Three studies were scored level II evidence, another three studies were of level III evidence and 11 were of level IV evidence. Despite the use of a comprehensive search strategy, all included studies were judged at high risk of bias. Eleven out of the 17 included studies were scored high risk of bias for all the domains and were often limited by sample size, not being representative of the target population, percentage of individuals agreeing to participate in the study, study design, randomization, confounding factors, blinding, data collection methods, and dropouts.

The studies were divided into six domains due to the variety of the subsections, which also reflect the heterogeneous nature of the outcomes and metrics used in the included studies. Indeed, the outcome measures varied not only across subsections but also within the same domain. Interestingly, in the management of aesthetic medicine complications domain, there were seven papers with a total of 14 patients with the same outcome measures. These include wound healing and limitation of scarring. However, the studies were either case reports or case series with a low level of evidence IV. The outcomes of the studies with a level of evidence of II included a self-designed questionnaire about the keloid properties, treatment results and aesthetic satisfaction in the study by Song et al.,[27] expression levels of the inflammatory factor interleukin-12p40, macrophage inflammatory protein (MIP)-1β, platelet-derived growth factor (PDGF)-BB and interleukin-1 receptor antagonist (Ra) in the study by Hao et al.,[13] and patient satisfaction and clinical improvement in the study by Fan et al.[15]

The paper by Oley et al. (2021) indicated that the success of HBOT is multi-factorial. This analysis showed that if the leucocyte count is more than 14 000/mm^3 and/or age is more than 67 years, HBOT is unlikely to be successful. If the patients' leucocyte level is <14 000/mm^3, the patient is younger than 67 years old and the platelet level is <233 000/mm^3, HBOT is likely to be effective.[29] From this study, one could be more selective with regard to which patients would benefit from HBOT and thus increase cost-effectiveness.

4.1 | Safety and possible complications

HBOT may be associated with possible complications such as sinus, pulmonary, or middle ear barotrauma, pulmonary, and central nervous system (CNS) oxygen toxicity and ophthalmic complications. Oxidative stress, resulting from the increased formation of ROS, seems to be the reason for the toxicity of hyperoxia. The paper by Barr et al., from 1972, mentioned oxygen fits or cramps that occur from oxygen toxicity. To avoid negative effects, each treatment should not exceed 3 atm and should not be longer than 2 h. Alternatively, the treatment could be split in two or three sessions per 24 h. Long treatment programs at higher pressures could also lead to a cataract-like clouding of the lens in arteriosclerotic patients.[30] At pressures beyond 3 atm, neurological side effects are inevitable due to a higher dissolved oxygen fraction. HBOT is also not suitable for claustrophobic patients. In addition, an untreated pneumothorax or concomitant use of certain chemotherapeutic agents such as cisplatin or doxorubicin are absolute contraindications to HBOT. Relative contraindications include pregnancy, seizures, active upper respiratory infections or sinusitis, implanted devices, hyperthyroidism, severe chronic obstructive pulmonary disease, asymptomatic pulmonary blebs or bullae, recent ear or thoracic surgery, uncontrolled fever, inability to equalize middle ear pressure, and congestive heart failure with ejection fraction less than 30%. Congestive heart failure is a relative contraindication because oxygen is a vasoconstrictor and HBOT may increase cardiac afterload. In view of the high level of oxygen that is used in the chamber, there is an increased possibility of a fire within the hyperbaric chamber. In the study by Fuller et al.,[31] the most reported side effects after HBOT at 2.4 atm, included middle ear inflammation and reversible myopia. A patient out of 17 subjects, in the study by Hachmo et al.[11] had moderate barotrauma to the ear which was treated conservatively and resolved completely. In the studies by Fan et al. (2021) and Friedmen et al. (2019), 34 and 356 patients were treated with HBOT, respectively, and none of them had any complications.[14,15]

4.2 | Cost analysis

This review also included cost analyses, which adds important information regarding the cost-benefits of providing HBOT in clinical

TABLE 5 Summary of the search results included in the table of this evidence-based review.

Aesthetic treatment modality	Author, date, and country	Study group and design	Study type (level of evidence)	Outcomes	Key results	Study weaknesses
Prevention of skin aging	Dennog et al., 1999, Germany[12]	Sixteen healthy non-smoking volunteers aged between 20 and 39 years They were all on a normal diet without vitamin supplementation They were given HBOT at 2.5 atm for three periods of 20 min each interspersed with 5 min of air-breathing Three subjects were given 800 mg daily of Vitamin E for 7 days before HBOT and another four were given 400 mg of N-acetylcysteine by mouth 1 h before HBOT. Subjects without supplementation were controls	Cohort study, Level III	Antioxidant status in human skin after exposure to HBOT	There was no significant effect of antioxidant vitamins A, C, and E with HBOT HSP70 was significantly induced in lymphocytes after a single dose of HBOT	Gender of volunteers not specified Limitations not mentioned
Rejuvenation	Hachmo et al., 2021, Israel[11]	Thirteen males with a mean age of 68.07 ± 2.5 years The subjects had a 3-month control period followed by 3 months of five times per week HBOT HBOT sessions were at 2 atm for 90 min each 5 × 5 mm biopsies were taken from the post-auricular area of subjects at baseline, after 3 months of HBOT and 1–2 weeks after the last HBOT session	Cohort study, Level III	To evaluate the effects of HBOT on normal aging skin	Following HBOT, there was a significant increase in elastic fiber length ($p = <0.0001$, effect size 2.71) and a significant decrease in fiber fragmentation ($p = 0.012$) There was also a significant increase in collagen fiber density following HBOT ($p = 0.0001$, effect size 1.10) There was a significant increase in CD31 ($p = 0.04$) and the number of vessels ($p = 0.02$) following HBOT HBOT also significantly decreased the number of senescent cells in the tissues. ($p = 0.033$)	Some of the authors work for AVIV Scientific Ltd and one of them is a shareholder Limited sample size Lack of a separate placebo group The skin was not evaluated clinically Effects on photoaging were not analyzed Other skin aging reverting mechanisms were not studied

(Continues)

TABLE 5 (Continued)

Aesthetic treatment modality	Author, date, and country	Study group and design	Study type (level of evidence)	Outcomes	Key results	Study weaknesses
Management of complications in aesthetic medicine	Tsai et al., 2014, Taiwan[17]	A case series of four reports following filler injection to the nose: Case 1: A 43-year-old male with immediate blanching and pain after hyaluronic acid filler injection. He was given antibiotics, NSAIDs, and HBOT. He was treated at 2–2.5 atm, for 80–120 min daily for 15 sessions. Non-surgical debridement was needed Case 2: A 23-year-old lady presented 4 days after 0.6 mL of calcium hydroxyapatite filler injection. She had immediate intense pain and blanching to the right side of her face. She was given antibiotics and two sessions of HBOT at 2.5 atm for 80–90 min daily. She had full-thickness necrosis on the nasal tip Case 3: A 42-year-old lady presented with a hyperemic and reticular pattern on her skin following a calcium hydroxyapatite filler injection 3 days previously. She had seven sessions of HBOT at 2.5 atm, 80–120 min. She did not need any debridement Case 4: A 20-year-old woman with unilateral nose blanching and severe pain after hyaluronic acid filler injection. She was referred in the following days and was given antibiotics and two sessions of HBOT at 2.5 atm for 80–90 min	Case series, Level IV	Wound healing and limitation of scarring	Case 1: Complete recovery Case 2: She had surgical debridement of the necrotic tip Case 3: Complete recovery Case 4: Complete recovery without scarring	No mention of amount of filler and residual scarring in the first case No mention of the final outcome in the second case Case 3 does not mention the location of injury and if there was residual scarring Case 4 does not specify how long after treatment she was referred and if she needed debridement Two types of fillers No standardized amount of HBOT sessions No standardized time that HBOT was given No standardization of additional medication
Management of complications in aesthetic medicine	Henderson et al., 2017, USA[18]	A 37-year-old lady self-injected a hyaluronic acid filler to the temple. Immediately after, she experienced hearing loss to her left ear, blanching to the left face, and severe pain. She had hyaluronidase treatment, topical nitro paste, and warm compresses. She presented after 9 h with ischemic changes to her left face and post-auricular area in addition to the hearing loss. Computed tomography angiography showed occlusion of the left superficial temporal artery. She was treated with enoxaparin, aspirin, dexamethasone, antibiotic, and intradermal lidocaine. She had six HBOT sessions twice daily, the initial two at 3 atm for 90 min and the following four treatments at 2.4 atm for 90 min with air breaks every 30 min	Case report, Level IV	Return of hearing loss and limitation of scarring	There was an improvement in appearance after 3 days and her hearing returned to baseline The residual scarring was only visible to herself after 1 year	One case The amount of hyaluronidase injected is not mentioned No photographs were published due to refusal of patient consent

TABLE 5 (Continued)

Aesthetic treatment modality	Author, date, and country	Study group and design	Study type (level of evidence)	Outcomes	Key results	Study weaknesses
Management of complications in aesthetic medicine	Hong et al., 2019, Korea[19]	A 43-year-old lady had 2 mL of hyaluronic acid filler injection to the nasolabial folds. She immediately had severe pain and hypoesthesia and was treated with hyaluronidase 24 h later. There was no improvement in symptoms so she was started on HBOT. She was given a session of HBOT at 2.8 atm for 135 min and another 42 sessions at 2 atm for 110 min. She also had aspirin, beraprost, IV alprostadil alfadex, topical nitroglycerin, and steroid ointment	Case report, Level IV	Wound healing and limitation of scarring	The wounds fully healed although with scarring	One case
Management of complications in aesthetic medicine	Worley et al., 2020, USA[20]	A 60-year-old lady injected with hyaluronic acid injections to the horizontal nasal crease, maxilla, and nasolabial folds. Two days later, she was treated for ecchymosis with a 532 nm laser. The next day she complained of pain in the left nasolabial fold and left eye and blurred vision in the left eye. She was diagnosed with keratitis and started on antibiotics. The symptoms worsened and she then experienced increasing pain in the left cheek and left nose and increasing vision loss. She was treated with 450 U of hyaluronidase to the left nasolabial fold, left nose, and glabella which led to an 80% improvement in pain. She was started on aspirin, ibuprofen, and nitroglycerin ointment. She again had a sudden deterioration and was treated with another 150 U of hyaluronidase and referred to HBOT. She had 9 90-min HBOT sessions	Case report, Level IV	Return of vision	Vision returned to baseline after 1 month	Total volume of filler is not mentioned The pressure with which HBOT was given is not mentioned One case
Management of complications in aesthetic medicine	Zeltzer et al., 2020, Belgium[21]	A 21-year-old lady who was injected with a hyaluronic acid filler to her upper lip presented with pain that started that same evening of the filler injection. The next morning she was given a block for pain relief by her practitioner. On Day 4, she was treated with three serial injections of 150 U of hyaluronidase. She was also given aspirin, piracetam, nadroparin, diclofenac, methylprednisolone, antibiotics, and topical nitroglycerin. HBOT was started on Day 11 for 7 days at 2.5 atm for 70 min each time. Contracture and hypertrophy were treated with triamcinolone acetonide, scar massage, and silicone sheets. Fat grafting was scheduled	Case report, Level IV	Wound healing and limitation of scarring	Residual contracture and hypertrophy	One case There is no mention of the final result following the scar management

(Continues)

TABLE 5 (Continued)

Aesthetic treatment modality	Author, date, and country	Study group and design	Study type (level of evidence)	Outcomes	Key results	Study weaknesses
Management of complications in aesthetic medicine	Hung et al., 2021, Taiwan[22]	A 31-year-old lady with sudden vision loss in the right eye during injection of hyaluronic acid filler to the nasal dorsum. She had severe retro-orbital pain during the injection and was injected with hyaluronidase in the treated area. She presented 30 min later. She was treated with mannitol and oxygen and advised to perform ocular massage every 4 h, topical brimonidine, oral acetazolamide, aspirin, IV methylprednisolone, 3 weeks of HBOT at 2.5 atm for 90 min daily. After 1 week of treatment, the patient developed skin pain and a violaceous plaque on the nasion and rhinion. She was prescribed oral and topical antibiotics	Case report, Level IV	Return of vision, wound healing, and limitation of scarring	Residual atrophic patch over the nasion and rhinion	One case Amount of hyaluronidase injected not specified
Management of complications in aesthetic medicine	Oley et al., 2022, Indonesia[23]	Case 1: A 55-year-old lady with injection of placental extract filler to her jaws 2 weeks prior, presented with inflammation on her right jaw. She was diagnosed with sialadenitis likely from blockage from the filler. She was treated with debridement, antibiotics, and seven consecutive HBOT sessions at 2.4 atm, lasting 90 min each Case 2: A 29-year-old lady presented with erythema on her cheek and chin following a thread lift procedure using barbed threads to her nasolabial folds and jawlines, 2 weeks prior. She had itching to the implanted areas the day following the procedure and had an exposed thread on her right cheek, 1 week following the procedure. She got no support from the clinic that implanted the threads and so she pulled the thread out herself. She presented with multiple small wounds on her cheek. She had antibiotics, nine sessions of HBOT at 2.4 atm for 90 min each, three times per week, and antihistamines Case 3: A 32-year-old lady presented with inflammation and blanchable erythema on the nasal tip a few weeks following hyaluronic acid filler injection to the nasal tip. She had 90-min HBOT sessions at 2.4 atm twice weekly	Case series, Level IV	Would healing, improvement in skin vascularity, and residual scarring	Case 1: the wound fully healed in 1 year Case 2: the wounds were less inflamed and had improved vascularization after 1 month Case 3: After 1 month her nose appeared less discolored	There is no mention of any residual scarring There is no reporting of the final outcome of Case 2 There is no mention of the total HBOT sessions in case 3

TABLE 5 (Continued)

Aesthetic treatment modality	Author, date, and country	Study group and design	Study type (level of evidence)	Outcomes	Key results	Study weaknesses
Management of complications in aesthetic medicine/surgery	Simman et al., 2022, USA[24]	Case 1: A 53-year-old lady following 1 mL of hyaluronic acid filler to the nasal tip and presented 10 days later with tip necrosis. She had HBOT at 2.5 atm for 25 sessions Case 2: A 30-year-old lady who had hyaluronic acid filler to her chin and developed complications 24 h after treatment. She was injected with hyaluronidase and referred 2 days later. She had five HBOT sessions at 2.5 atm and stopped due to COVID illness Case 3: A 46-year-old woman with a history of sleeve gastrectomy, adhesiolysis, open cholecystectomy, mastopexy augmentation, gluteal lift, torsoplasty, abdominoplasty, and liposuction. She presented 17 days after the abdominoplasty with a non-healing wound in the lower abdomen. She was given 39 HBOT sessions at 2.5 atm and surgical debridement Case 4: 73-year-old smoker who had a basal cell carcinoma and flap reconstruction on the nasal dorsum with flap tip necrosis. She had 20 HBOT sessions at 2.5 atm	Case series, Level IV	Wound healing and limitation of scarring	Case 1: Minor pigmentary changes that could easily be covered with make-up Case 2: Complete resolution Case 3: Complete healing. Case 4: Complete resolution	No mention of the length of the HBOT sessions given No mention of the amount of filler in Case 2 Case 4 is not a cosmetic case No standardization of the amount of HBOT sessions given No mention of residual scarring There are no standardization of hyaluronidase use
Management of complications in aesthetic surgery	Guler Alis et al., 2018, Turkey[25]	A 32-year-old lady had a deterioration of vision in her left eye immediately after rhinoplasty. She presented 1 week after surgery. Fundoscopic examination revealed a pale area in the inferior part of the macula. She had three sessions of HBOT, terminated as per the patient request	Case report, Level IV	Return of vision	There was little progression in the visual field test	One case HBOT protocol not mentioned

(Continues)

TABLE 5 (Continued)

Aesthetic treatment modality	Author, date, and country	Study group and design	Study type (level of evidence)	Outcomes	Key results	Study weaknesses
Management of complications in aesthetic surgery	Friedman et al., 2019, Israel[14]	Three hundred fifty-six female patients over 18 years of age, who had an abdominoplasty done from January 2012 to November 2017, using the same techniques They were all offered HBOT Eighty-three patients had HBOT preoperatively HBOT was given at one to three daily sessions at 2 atm for 90 min	Cohort study, Level III	Postoperative complications such as necrosis, seroma, infection, hematoma, wound dehiscence, and hypertrophic scarring	The HBOT group had significantly less postoperative complications when compared with those who did not have HBOT (8.4% versus 32.6%) $p = <0.001$ Seventeen patients from the group that were not given HBOT, had necrosis. None from the HBOT group had necrosis. $p = 0.016$ In a multivariate analysis, preoperative HBOT was an independent factor of protection against complications after the surgery. $p = <0.001$	Female patients only HBOT sessions not standardized Retrospective study Patient self-selection
Hypertrophic and keloid scarring	Liu et al., 2018, China[26]	Forty-five patients with keloids on the face treated between January 2013 and January 2016 There were 35 men and 10 women aged between 16 and 36 years Multiple incisions were made in the keloid in the direction of the facial aesthetic lines. The keloid skin was elevated as skin flaps. The keloid tissue was then removed through the same incisions and the overlying skin replaced and sutured. Radiotherapy and HBOT were done postoperatively. They were examined at 6 and 12 months postoperatively	Case–control study, Level IV	Whether the patient is fully (with normal scar) or partially cured (with a hypertrophic scar in part or all of the scar) or has a keloid recurrence at the surgical site	All the patients recovered well No acute complications Thirty-three patients were fully cured and seven were partially cured Five patients had recurrence There was no scar atrophy Thirty-six patients thought that the result was good, four patients thought that it was acceptable and all those who had recurrence of the keloid thought that the result was poor	HBOT protocol was not specified There was no mention of when the sutures were removed The time at which the patients used silicone sheets and pressure bandages was given as a range Small cohort

TABLE 5 (Continued)

Aesthetic treatment modality	Author, date, and country	Study group and design	Study type (level of evidence)	Outcomes	Key results	Study weaknesses
Hypertrophic and keloid scarring	Song et al., 2018, China[27]	Two hundred forty patients with keloids on the chest or shoulder One hundred thirty-four individuals were given HBOT in addition to excision and radiotherapy (33 men and 101 women), aged between 16 and 52 years One hundred six individuals were treated with excision and radiotherapy only. There were 32 men and 75 women aged from 17 to 58 years Radiotherapy was given at postoperative Days 1 and 7 at 900 cGy each HBOT was given for 60 min at 2 atm after the operation for 2 weeks	Randomized controlled trial, Level II	Self-designed questionnaire enquiring about scale of keloid, pigmentation, vascularity, pliability, height of keloid, and degree of satisfaction with treatment Treatment results were graded as: fully cured, partially cured, and keloid recurrence Aesthetic satisfaction was classified as: excellent, good, or dissatisfied	Median follow-up was 20.5 months for the HBOT group and 21.0 months for the no HBOT group Efficacy and satisfaction rates for the HBOT cohort were significantly better than those not given HBOT. $p = <0.05$ There was higher inflammatory marker expression in the cohort not given HBOT when compared to the cohort given HBOT. The difference was significant. $p = <0.001$	Limitations not mentioned Funding not mentioned
Hypertrophic and keloid scarring	Hao et al. 2020, China[13]	Thirty patients, 15 men, and 15 women aged between 21 and 52 years Ten keloid samples (from five men and five women) were taken from individuals treated with HBOT for 60 min at 2 atm, daily for 7 days prior to sample collection. Another 10 samples from five men and five women, from patients not treated with HBOT. The last 10 normal skin samples were taken from five men and five women without obvious scarring. All tissue samples were taken from the chest Age did not differ in the sample group ($p = <0.05$)	Randomized controlled trial, Level II	Expression levels of the inflammatory factors interleukin-12p40, macrophage inflammatory protein (MIP)-1β, platelet-derived growth factor (PDGF)-BB, and interleukin-1 receptor antagonist (Ra)	IL-12p40, MIP-1β, and PDGF-BB we higher in the group with keloids not treated with HBOT. IL-1Ra was lower. These were significantly different. ($p < 0.05$) The inflammatory response significantly decreased after 7 days of HBOT with a decreased expression of IL-12p40, MIP-1β, and PDGF-BB and a higher expression of IL-1Ra	Small sample size

(Continues)

TABLE 5 (Continued)

Aesthetic treatment modality	Author, date, and country	Study group and design	Study type (level of evidence)	Outcomes	Key results	Study weaknesses
Hypertrophic and keloid scarring	Hao et al., 2022, China[28]	Fifteen patients with keloids from 2020 and 2021 Eight patients had ear keloids, 3 had keloids on the face, 3 had them on the shoulder and one had keloids on the chest There were five men and 10 women in the cohort with ages ranging from 19 to 40 years Thirty-five Keloid Subepidermal Vascular Network Flaps were constructed. All the patients had adjuvant radiotherapy and HBOT	Case–control study, Level IV	Perfusion of the flap on Day 1 postoperatively and on the day of suture removal Keloid recurrence Satisfaction with the procedure	Perfusion on Day 1 postoperatively was 120.4013 and 168.6900 on the day of suture removal ($p = 0.02249$) Two flaps had partial necrosis Effective safe length/width ratio was 1.05	The patient keloid volume and skin color were not standardized Short follow-up time Small cohort Funded project HBOT protocol not specified
Hair transplantation	Fan et al., 2021, China[15]	Thirty-four patients with type II-IV alopecia randomly assigned to two groups The control group had FUE procedure alone while the other group had the procedure combined with HBOT at 2 atm for 60 min daily for 7 days postoperatively	Randomized controlled trial, Level II	Patient satisfaction Clinical improvement	Pruritus and folliculitis were significantly decreased in the HBOT group (11.8% vs. 35.3%) The HBOT group had a lower shedding rate postoperatively Graft survival rate at 9 months was the same for both groups All the patients were happy with the final result	Funded study Small cohort

FIGURE 2 Distribution of publications according to year and country.

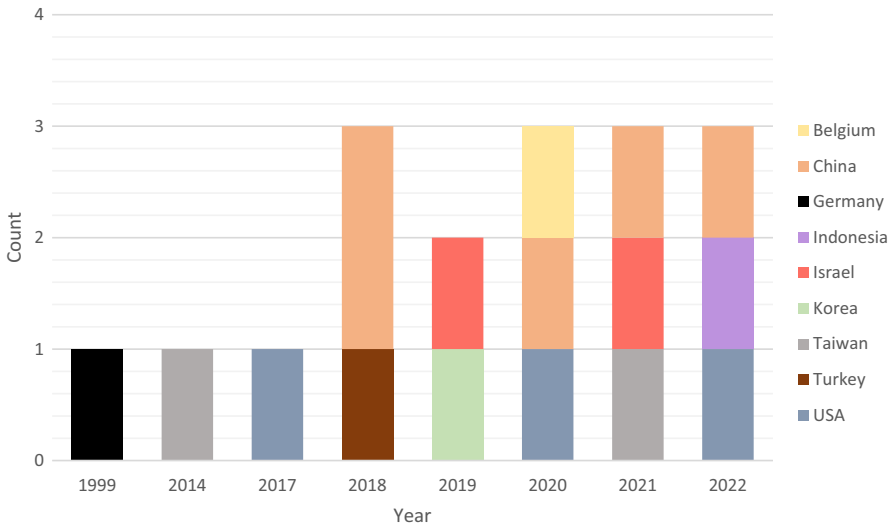

TABLE 6 Risk of bias.

Authors and Publication Year	Selection bias	Study design	Confounders	Blinding	Data collection method/s	Withdrawals and dropouts	Overall global rating
Dennog et al. (1999)	High	High	High	High	High	High	High
Tsai et al. (2014)	High	High	High	High	High	Not applicable	High
Henderson et al. (2017)	High	High	High	High	High	Not applicable	High
Song et al. (2018)	Low	Low	High	High	High	Moderate	High
Liu et al. (2018)	Moderate	High	High	High	High	Not applicable	High
Guler Alis et al. (2018)	High	High	High	High	High	Not applicable	High
Friedman et al. (2019)	High	High	High	High	High	High	High
Hong et al. (2019)	High	High	High	High	High	Not applicable	High
Hao et al. (2020)	Low	Low	High	High	High	Moderate	High
Zeltzer et al. (2020)	High	High	High	High	High	Not applicable	High
Worley et al. (2020)	High	High	High	High	High	Not applicable	High
Fan et al. (2021)	Low	Moderate	High	High	High	Moderate	High
Hachmo et al. (2021)	High	High	High	High	Low	Moderate	High
Hung et al. (2021)	High	High	High	High	High	Not applicable	High
Hao et al. (2022)	Low	Moderate	High	High	High	Moderate	High
Oley et al. (2022)	High	High	High	High	High	Not applicable	High
Simmam et al. (2022)	High	High	High	High	High	Not applicable	High

settings. As per the "what clinic" webpage, there are 46 clinics offering HBOT worldwide. In China, 60 min of hyperbaric oxygen at 2 atm cost less than $80 per patient. However, Shuck et al. (2017) claimed that an average HBOT session costs $400 but can vary from $100–$1000. The webpage, "costhelper health" states that the cost of hyperbaric oxygen therapy for those without health insurance may fluctuate from $100 dollars at an HBOT clinic to more than $1000 at a large medical hospital. At a wellness center in the USA, the treatment costs $125 per hour. Moreover, at a particular spa, in the USA, each session costs $160. At an aesthetic parlor in England, HBOT sessions for 60 min at 1.5 atm are sold as a pack of 10 sessions at £995, equivalent to $1277 or $128 per session. Thus, the average price is that of $138. From this research, as per Table 7, the cheapest 1-person hyperbaric chambers that go up to 1.3 atm cost between $4999 and $26 995. Ones that go up to 2.0 atm cost between $53 000 and $80 629. A business would need to decide how many persons do the chamber needs to accommodate. This would depend on the flow and type of clients and whether the clients come alone or as couples. It is also imperative to also conduct a market research about what atmospheric pressure the clients are looking for, if enquiring about it at all, the level of comfort they are looking for and whether they are willing to compromise on comfort for a cheaper price. If a business decides to go for the cheapest chamber that goes up to 1.3 atm, they would require around 36 uses to break even. Instead, with the cheapest chamber that goes up to 2 atm, 384 uses are needed for the business to start making profit.

TABLE 7 Market research of hyperbaric chamber prices.

Company	Pressure (atm)	Diameter (inches)	Price
Oxyhealth®	1.3	21	$9000
	1.3	27	$15000
	1.3	32	$23000
	3	42	$136100
Oxynova™	1.3	33	$26995
	1.3	36	$32995
	1.4	22	$16995
	1.4	28	$23995
Henshaw hyperbaric chambers	1.3	28	$17185
	1.3	32	$22915
	1.3	36	$25462
	1.3	39	$28015
	1.4	32	$24061
	1.5	28	$24729
	1.5	30	$53483
	1.5	34	$62397
	2	40	$80629
Rehabmart	1.3	27	$4999
	2	37	$53000
Hypotech®	1.5	35	$35942
	1.5	67	$77330
	2.0	67	$80597
	3.0	35	$81686
	3.0	87	$76241
	6.0	87	$174264

4.3 | Limitations

The main limitation of this review is that it is not a systematic review. The authors have decided to use the Best BETs methodology as the evidence available is not of very high quality, and thus, rigorous appraisal would discard many of the papers. Best BETs assimilates the best available answer at the present time with the available literature. Moreover, studies in other languages rather than English were excluded from this review due to no funding for translations. This could have potentially missed relevant studies. In the studies where *p* values are worked out, the number of participants that support those findings is not mentioned. Furthermore, most of the studies were of poor quality and with a high risk of bias due to the reasons mentioned in the discussion.

5 | CONCLUSION

Our findings appear to be largely in line with the more restrictive review from 2014. They found conflicting evidence on how the mechanism of action of HBOT can have a beneficiary effect in aesthetics. This is consistent with our findings that could not ascertain whether the treatment is justifiable. To our knowledge, this is the first comprehensive evidence-based review extending the research to a broader and more inclusive field of aesthetics. Randomized controlled studies with longer follow-up and better patient selection are needed to be able to generate a reliable conclusion.

CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare in relation to the content of this article.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the Supporting Information of this article.

ETHICS STATEMENT

Authors declare human ethics approval was not needed for this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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