**JetPeel - New Aspect for Skin Rejuvenation**

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**Abstract**

A new device for detaching epidermal cells from the dermal layer was developed by adaptation of the principles used in jet propulsion. A jet stream of oxygen and fluid presents a two-pronged approach to rejuvenate the skin. Experimental results indicate that the pressure at the stagnation zone in the treated area could reach 3.5 atmospheres. It must be noted that only pure oxygen is present at that site. The fluid streaming accompanied by the cooling oxygen gas (Joule-Lentz effect) causes skin changes. The presence of high-pressure oxygen on the skin surface is due to the variation in the thermodynamic state. In the JetPeel, oxygen and liquid are applied simultaneously. Thus, some of the oxygen gas dissolves into the liquid causing a rise in the oxygen concentration. Therefore rise is achieved in both the gaseous and liquid phases of the oxygen concentration. The result is an increase in the concentration of oxygen in the superficial layers of the skin. The oxygen gas phase lasts only during that instantaneous reaction. As soon as it penetrates stratum corneum it dissolves into the extra cellular fluid and the capillary plasma.

Injury to the epidermis causes also an increase in oxygenation of the cutaneous hemoglobin. This was due to the increased atmospheric oxygen uptake. Any damage to the epidermis promotes the oxygenation of the hemoglobin by the atmospheric oxygen. Oxygenation of the hemoglobin in the skin causes significant changes; both the lipid concentration and the stratum corneum thickness are reduced. Quantitative evaluation of the reflected diffusion spectrum in the skin revealed significant changes in hemoglobin oxygenation in areas where reduced lipid concentration and reduced stratum corneum thickness were also found. This may indicate that the removal of the superficial keratin layer of the skin increased the oxygen diffusion through it.

The JetPeel is capable of removing the epidermis layer of the skin, thereby increasing the oxygenation of the dermal layer.

**Introduction**

Under normal conditions, atmospheric oxygen can supply the upper skin layers to a depth of 0.25-0.40 mm. This is 3-10 times deeper than has been calculated previously (Fitzgerald, 1957). The hole epidermis and the upper corium can therefore be supplied with oxygen from the atmosphere. This may have significant consequences with regard to the treatment of lesions. Treatment to improve tissue oxygenation has a positive effect on the skin. It stimulates and rejuvenates the healing processes in aging or damaged skin. Cellular functions such as growth and metabolism are affected by the partial oxygen pressure (pO₂) in the extra cellular compartment.

The pO₂ levels in healthy skin vary between 10 to 40 mmHg, whereas, in pathological processes, such as tumors and hypoxic wounds oxygen levels fall below 5 mmHg. About fifty percent of the oxygen consumption in the skin is supplied by diffusion from the surface. This oxygenation becomes assumes importance in cases of arterial insufficiency. The oxygen permeation through the upper layers and the oxygen pressure within the skin determine the amount of atmospheric oxygen uptake.

In 1987 Baumgärtl, using needle electrodes to measure pO₂ in skin, demonstrated that a minimum pO₂ value could be observed between the surface and the capillary bed. This indicated that there is an O₂ flow through the epidermis in the upper layers of the skin. The recent development of fluorescence-based O₂-flow electrodes for measuring oxygen flow has meant that the phenomenon could be studied directly. More recently Stücker et. al. showed that by using simultaneous measurement of oxygen flow, transcutaneous pO₂ and laser Doppler perfusion, the epidermal oxygen uptake from the atmosphere is in balance with the blood-borne (haematogenic) oxygen supply. These measurements of oxygen flow and previous measurements of pO₂ profiles indicated that capillary blood flow in the skin,
at normal skin temperature, might not be a contributing factor to the oxygen supply to the super facial layers. In a study evaluating the contribution of the blood flow to the oxygen supply of the skin, tc\(_{O2}\) (transcutaneous oxygen flow), recorded at normal skin surface with partial oxygen pressure of (163 ± 10 Torr), was 0.53± 0.27 ml \(O_2\) min\(^{-1}\) m\(^{-2}\).

A 5 min disruption of blood flow resulted in an increase of 9.5 ± 6.3 % in tc\(_{O2}\). The value of tc\(_{O2}\) was unaffected by the age of the subject. Published data on the oxygen diffusion properties through the skin and simulations of intracutaneous profiles of oxygen partial pressure show that under these conditions, the upper skin layers, to a depth of 0.25-0.40 mm, are supplied, almost exclusively, by external oxygen, whereas the oxygen transport from the blood plays a minor role. Therefore, inadequate capillary oxygen transport cannot be the cause of the superficial skin defects.

Increased oxygen concentrations in the skin will result in its escaping to atmosphere. To counteract it, one can use the oil phase of an emulsion, which encapsulates the hydrogen peroxide molecule, creating a barrier in the skin. This theory claimed that the hydrogen peroxide in the capsule increases the skin surface pressure up to one or more atmospheres, and is responsible for oxygen penetration into the skin. These claims are not supported by physical evidence, or experimental data. If the authors meant that the high pressure in macroscopic vesicles are responsible for their claim, they did not take into consideration the centrally oriented vectors of the vesicle surface forces, which forms the ideal spherical shape of the superfine liquid covering. When the vesicle reaches the skin, the delicate balance of the forces is disrupted and the vesicle bursts letting the oxygen escape into the surrounding atmosphere.

The problem of oxygen supply becomes very crucial with aging. Atmospheric oxygen has declined steadily over the last 100 years. At the same time, levels of toxic gases and contaminants in the air have increased. Our skin, which thrives on a quality and consistent supply of oxygen, has suffered in this opposing battle for oxygen and is losing its fight to retrain a youthful and healthy appearance. By age 30, skin has already lost 25% of the oxygen it started with. By age 40, almost 50% of the skin's ability to utilize and retain oxygen has been impaired. Less oxygen at the dermal layer (surface) of the skin results in more wrinkles, fine lines and dull looking skin. This is the reason why the JetPeel device was developed.

**Materials and Methods**

The JetPeel device is based on a new, novel and innovated technology for skin rejuvenation. The technology, which utilizes the principles of gas dynamics commonly used in aeronautics and space sciences, was adapted to fulfill cosmetic needs. In this technology, pressurized oxygen is used to accelerate a liquid agent to cause erosion of the skin surface. In this technology fine needles were placed in the axial direction within a complex supersonic nozzle. The result is similar to the one seen in STOVL (short takeoff/vertical landing) aircraft. The impact of supersonic jet streams on the surface of the skin will produce forces that cause erosion of the skin surface. Further adjustments to the jet spread and the size of the droplets will maximize this effect. Most of the fluid impact is typically located at the anti-nodal (highest deflection) site while the maximum strain is usually found elsewhere.

The schematic presented in Alvin F.C. and Iyer K. G was used for experimental purposes. The optimal configuration for the design of the headpiece of the JetPeel must take into consideration, as the main force that yields the best results, the velocity forces generated by impact of the triple supersonic jets. The flow field schematic illustrates the forces created by the interaction between the jet stream and the plates.
The disruption of the epidermis causes increase in cutaneous hemoglobin oxygenation due to the increase in atmospheric oxygen uptake. Any damage to the epidermis will increase the oxygenation of the hemoglobin by the atmospheric oxygen. Oxygenation of the hemoglobin in the skin yielded significant changes; both the lipid concentration and the thickness of the stratum corneum layer were reduced. Quantitative evaluation of the reflected spectrum of diffusion in the skin reveals significant changes in hemoglobin oxygenation in the skin areas where the reduced lipid concentration and the reduced stratum corneum layer were found. This may indicate that the removal of the superficial keratin layer of the skin increased the oxygen diffusion through it.

A study, measuring the impact of the flow field generated by the triple supersonic jet, was conducted in the Tavtech Ltd. Laboratory. The experiment included three circular jet nozzles (Fig.1) with throat diameter of 0.5mm generating an exit velocity up to 1.8 Mach. The nozzle exit diameter was 0.57mm and the nozzle separation 1.1mm. High-pressure (3000psi) storage tanks coupled to high displacement air compressor supplied the air to the jets. Measurements of the stagnation pressure/ambient pressure yielded the optimal expansion of the jet stream in the nozzles. The jet flow was seeded with sub micron water droplets generated by the suction effect.

Fig.1 Flowfield Schematic

Results

Measurement of the increase in flow velocity was performed using a three-hole pressure probe, which was positioned in coaxial direction to flow and at various distances from the primary jet flow exit.
Fig.2 Measurements of the pressure at the skin as a function of the distance from the primary source of the jet flow.

The pressure at the stagnation zone could reach 3.5 atm. It must be noted that only pure oxygen is present at that site. The fluid stream through the nozzle that was accompanied by the gas cooling (Joule-Lentz effect) causes the deviation in the measurements of the surface oxygen. The drop in temperature may reach 10°C. The presence of high-pressure oxygen on the skin is due to the variation in the thermodynamic state. In the JetPeel, oxygen and liquid are applied simultaneously. Thus, like all gases, some of the oxygen dissolves into the liquid causing the concentration of gas to rise as the pressure increases and temperature drops.

All these contribute to the rise in both the gaseous and liquid phases of the oxygen concentration. The result is an increase in the concentration of oxygen in the superficial layers of the skin. The oxygen gas phase lasts only during that instantaneous reaction. As soon as it penetrates stratum corneum it dissolves into the extra cellular fluid and the capillary plasma.
Photographs of a histological preparation of the skin cross-section. A - is the JetPeel treated section and B - is the control non-treated skin segment. A. At one of the edges of the specimen the epidermis is missing. The missing epidermis appears to be at the dermoepidermal junction. The transition zone from normal to missing epidermis is short, not abrupt. At the beginning the superficial layer of keratinocytes is missing and then stepwise only few cells of basal cells are left before the epidermis is completely missing. No inflammatory response is present. Hair follicle appears to be without significant changes. Few vesicles of different size are present in the upper reticular dermis more or less the size of lipocytes. The epidermis adjacent to the missing are is without significant changes. Note the small oxygen vacuoles in skin extending deep into the dermis. The intercellular vacuolization indicates that cutaneous oxygenation and revascularization is taking place.

The disruption of the epidermis by wall jet flow (Fig.1) causes increase in cutaneous hemoglobin oxygenation due to the increase in atmospheric oxygen uptake. Any damage to the epidermis will increase the oxygenation of the hemoglobin by the atmospheric oxygen. Oxygenation of the hemoglobin in the skin yielded significant changes; both the lipid concentration and the thickness of the stratum corneum layer were reduced. Quantitative evaluation of the reflected spectrum of diffusion in the skin reveals significant changes in hemoglobin oxygenation in the skin areas where the reduced lipid concentration and the reduced stratum corneum layer were found. This may indicate that the removal of the superficial keratin layer of the skin increased the oxygen diffusion through it.

**Discussion**

The hydro mechanical effects of the JetPeel cause scrapping of the superficial keratinized layers of the skin thereby increasing oxygen penetration. The stream of high velocity two-phase oxygen and droplets of liquid stretches the skin and the flow, directed in parallel to skin, causes cell detachment
from the skin surface. This powerful stream is capable also of penetrating the skin pores and crevices, as well as acne lesions, and removing tissue debris. Since bacteria causing infection are anaerobic, they cannot survive the exposure to oxygen.

The interaction between the spray of high frequency oxygen droplets and the skin will also cause a multi frequency massaging effect. The circulation is also stimulated by the scanning pattern of the JetPeel nozzles over the treated area of the skin. Addition of nutrients, drugs and/or vitamins to the fluid solution used in the JetPeel will increase the benefits to skin.

Histological studies show that skin creases or wrinkles are formed following a series of major cellular changes: During the sub-clinical phase of aging (ages 35-45), there is a gradual and progressive slowing down of the cellular turnover and regeneration which in turn causes thinning of the skin. As a result, the normally undulating ridge-like dermal-epidermal interface (DEI) becomes flat. Thus, there is a reduction in the surface area available for metabolic exchange at the junction of the superficial epidermis with the deeper dermis layer.

Reduced nutrition to the epidermis, due to aging, is one of the factors that weakens and depletes the cells. Without proper nutrition to the epidermal cells the cellular metabolism is undermined. Furthermore, transport of the by products of cellular metabolism such as free radicals is diminished. Accumulation of free radicals in the cytoplasm of the cells may lead to undesirable mutational damage and eventually to cancer.

The DEI junction is usually composed of type IV (a multi layered structure or basal layer) and type VII (anchored to the layered structure) collagen. The progressive loss of nutrients in this area slows the circulation of the messengers that promote neo-synthesis of collagen creating a vicious cycle. Without optimal amounts of collagen, the skin sags and further depletion of nutrients is induced. Paradoxically, mature aging skin contains more elastin, which is used by the body to fill the empty space created by the loss of collagen. The elastin, unfortunately, is fragmented, calcified and contains an excessive amount of lipids. In addition to the loss of skin thickness due to lack of collagen support, the aging skin is looser and lacks elasticity. These are the two properties that are the hallmark of wrinkles.

The process of aging and the appearance of wrinkles are accelerated during the clinical phase of aging (age 45 and up). By age 50, very few men and women can escape wrinkles. The difference only lies in the degree of the blemishing. A wrinkle, very simply, is caused by the reduction of collagen. For improving oxygen supply to the skin the preference is to remove the border between the inner and the outer layers of the tissue.

It has been reported (Nataloni) that topical oxygen treatment enhances healing. The rates of epithelial growth and VEGA synthesis increase and inturn, induce angiogenesis and formation of collagen type I and III that accompany revascularization. Furthermore, it was claimed that eliminating the barrier between the superficial and deep layers of the skin improves the availability of the deep vascular supply of nutrients and oxygen molecules, dissolved in the plasma, to reach the skin. It will also allow deeper penetration of the atmospheric oxygen into the skin. (Davis SC Sullivan TP Cazzangia AL Sander EL Eaglstein WH Mertz PM)

Because there is a virtually unlimited supply of oxygen molecules in the atmosphere, the dissolved O₂ molecules that leave the plasma to bind with hemoglobin are quickly replaced by others. The once bound, oxygen no longer exerts a gas pressure. Therefore, as the hemoglobin combines with the oxygen more oxygen gains entrance into the blood until complete saturation is achieved. The level of saturation is dependent on the PaO₂. This dynamic process is instantaneous and at any given moment O₂ molecule is either in bound or dissolved form. However, depending on the PaO₂ and other factors, a certain amount of the O₂ molecules will be dissolved and certain percentage will be bound. The free or
dissolved oxygen molecule register a partial pressure of 95mm Hg and the red blood cells in the skin contain a total of 15gm/dl hemoglobin.

The cell capability of utilizing unbound oxygen is further strengthened by the fact that a 5% oxygen atmosphere is used in tissue culture technology. This fact indicates that the cultured cells respiration is dependent on the gaseous oxygen. The oxygen is dissolves in the nutrient media and becomes available to the cells. Therefore the atmospheric oxygen that dissolves in the tissue fluids and plasma can supply the cells directly as unbound oxygen or indirectly by binding to the plasma hemoglobin.

According to Skaper et al. normal cell metabolism results in a continuous generation of reactive oxygen species, such as the super oxide radical or the nonradical hydrogen peroxide. Therefore an imbalance between the reactive oxygen and the antioxidant defense mechanisms of a cell may lead to excessive production of oxygen metabolites. The molecular mechanisms responsible for biochemical damage are complex, but it has been established that super oxide radical and hydrogen peroxide are precursors of other reactive species, such as the hydroxyl radical. However, following peeling of the epidermis, the wound-healing cascade that ensues will include neovascularization and epithelialization. This will contribute to restablishing adequate circulation of tissue fluid and continuing clearance of the by products of cellular metabolism.

Under normal conditions, atmospheric oxygen can supply the upper skin layers to a depth of 0.25-0.40 mm. This is 3-10 times deeper than has been calculated previously (Fitzgerald, 1957). The whole epidermis and the upper corium can therefore be supplied with oxygen from the atmosphere. This may have significant consequences with regard to the treatment of lesions.

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**Conclusion**

The peeling of the keratinized epidermis initiates the physiological process of wound healing. Both revascularization and epithelialization are initiated. The growth and spread of the epithelial cells is enhanced by the ample source of bound and unbound oxygen molecules. Therefore, cell respiration and cell metabolism proceed due the readily available atmospheric oxygen and the hemoglobin bound oxygen. The utilization of hemoglobin bound oxygen is enhanced by the penetration of the gaseous atmospheric oxygen into the tissue fluids and plasma. Clearing the physiological metabolic by products of cellular metabolism is accomplished by the rapid in growth of a vascular network.

**References**

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