In-office photobiomodulation to enhance clinical treatment

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Introduction:

Clinical outcome is influenced by many factors and can be enhanced to improve the results utilizing the body and its natural factors. Diet and managing the patient's health play a key role in how their systems react to clinical treatment that affects the soft and hard tissues of the body. But there are ways to enhance the bodies healing and regeneration by influencing cells within the soft (gingiva, muscle, skin) and hard tissue (bone). Photobiomodulation (PBM) has been increasingly reported to provide positive effects to various areas of the body when applied to that tissue without any side effects in a non-invasive manner.

Photobiomodulation is defined as the utilization of non-ionizing electromagnetic energy to trigger cellular photochemical changes within structures that are receptive to those photons. In particular, mitochondria are receptive to this process, where at the cellular level, near infrared light (NIR) and visible red energy is absorbed by the cell's mitochondria. Those mitochondria produce energy called "ATP" (adenosine triphosphate) for cellular use. PBM may result in the increased production of mild oxidants (ROS), nitric oxide (NO), (ATP), and cyclic adenosine monophosphate (cAMP) which initiate cell proliferation and induce the signal cascade effect.[1] The process additionally creates ROS, which leads to cellular repair and healing. This process unclogs the chain that has been clogged by NO which is then released back into the system. [2] Nitric oxide is a molecule that our body produces to help its cells communicate with each other with communication occurring by transmission of signals throughout the body. [3] Additionally, nitric oxide helps to dilate the blood vessels and improve blood circulation. Those factors can lead to increased expression of genes related to protein synthesis, cell migration and proliferation, anti-inflammatory signaling, anti-apoptotic proteins, antioxidant enzymes. Stem cells and progenitor cells appear to be particularly susceptible to LLLT. [4] The key to the entire process is a mitochondrial enzyme called cytochrome oxidase c, a chromophore, which accepts photonic energy of specific wavelengths when functioning below par. As the mitochondria absorb those wavelengths of light energy, producing more ATP energy transportation in the cells is boosted leading to increased cell proliferation. That cell proliferation via photobiomodulation increases the body's natural healing process.

Wavelengths and their effects on tissue:

Light is measured in nanometers (nm) and expressed as a wavelength. Natural light (white light) is a combination of various wavelengths. But specific wavelengths have different penetration and affects on the body when exposed to it and fall into color specific ranges. (Figure 1) As the wavelength increases deeper penetration is observed and different tissue is affected, with near-infrared (NIR) having the deepest penetration and ultraviolet (UV) the least. Sunburns and tans are caused by UV (100 to 380 nm) light and thus the superficial skin is affected with little to no affect on deeper tissues and in some individuals may lead to skin cancer. [5]

Blue (450-470 nm) light has been surrounded by controversy relating to the premise that the margin between 'safe' blue light and potentially damaging (UV) light has not been well defined. Clinical results have reported benefits on inflammatory lesions on subjects with acne. This wavelength of light can induce beneficial and adverse effects, depending on the dose and on the spectrum width of the

exposure. [6] Reports have demonstrated that blue light has a positive effect to partially prevent skin flap necrosis and when combined with red light can enhance the survival of random skin flap by improving angiogenesis. [7] So, utilization of PBM with blue light can augment the affects of red light aiding in healing of incisions, cuts and other alterations to the surface tissue (skin and gingiva). Blue light was reported to stimulate keratinocyte differentiation aiding in restoring the skin barrier function. [8]

Green (510-540 nm) light is absorbed into the skin where it helps to lighten hyper-pigmentation spots revealing a brighter complexion. Pigmented areas on the skin (brown spots or freckles),have many causes and can occur in all skin types. Hyperpigmentation is characterized by darker areas of the skin or gingiva related to overproduction of melanin. The green wavelengths target melanocytes, the melanin-producing cells located in the deeper layer of the skin's epidermis, inhibiting production of excess melanin, thereby preventing it from travelling to the skin's surface, and breaking up melanin clusters to lessen existing discoloration. As a result, dark spots slightly fade while blending with the surrounding tissue tone. [9] Additionally, the light aids in increasing cell growth enabling wound repair of the skin and gingiva. The effect also has anti-inflammatory properties that soothe the surface of the skin. Green light has shown a therapeutic effect on basal cell carcinoma. [10] Additionally, it accelerates wound healing and has positive effects on treatment of acne and other skin irritation issues. [11] Reported that green light was more potent stimulating proliferation and migration of endothelial cells than clinically well-established red light therapy. [12] Further they reported that blue and green wavelengths produced a stimulating effect with increased osteoblast differentiation. With the shallower depth of penetration of those two wavelength ranges compared to red and NIR, this works well intraorally where the osseous structure is below gingival tissue with no interspersed muscle that may prevent contact with the boney area. Ideally, it may be considered to utilize red/NIR light for expansion and proliferation of stem cells and use blue/green light for differentiation into progenitor cells with a combination of those for the best overall effects.

Yellow (580-600 nm) light has slightly deeper penetration then blue and green light reaching the dermal area with has a healing, anti-inflammatory and analgesic effects with regenerative affect on the skin. This wavelength is effective with skin conditions involving redness, swelling, and other effects related to pigmentation. [13] In vitro and in vivo studies have demonstrated the ability of yellow LED therapy to trigger skin collagen synthesis and to reduce MMP expression[14] Rejuvenation effects have been reported followed by treatment with yellow. [15]. Acne, whether in adolescents or adults can be challenging to eliminate with traditional methods and create esthetic issues that and LLLT treatment utilizing light in the yellow range has demonstrated to be effective in treatment of acne. [16] Dermal scars are also an esthetic issue especially when present on the face and may not be coverable by makeup in female patients and an issue for male patients too. Scar reduction has been reported using this wavelength of light and has esthetic implications in those patients who are concerned with the presence of scars related to either prior surgical treatment or previous trauma. [17] This also applies to treatment of keloid. [18] Additionally, it has been reported yellow wavelengths are an effective treatment for thinning hair and baldness related to androgenetic alopecia and alopecia areata. [19]

Red (610-775 nm) light has been documented to provide healing to the irradiated tissues with deep penetration into the skin and underlying structures, where the cells can absorb and use it. Mitochondria in the cells absorb those light particles, which then produce ATP, which is the energy source for the cells. The extra energy creates a cellular response allowing the cells to better respond to damage and rejuvenate themselves. Irradiation with red light generated a much lower amount of

ROS when compared to the nonirradiated cells. [20] Another study suggested that the more stressed fibroblasts cells are the better they respond to photobiomodulation with red wavelengths. [21] Those red wavelengths increased cell proliferation and viability while aiding in wound healing via accelerated cell migration rate. [22] It modulates dermal fibroblasts to increase gene expression responsible for enhancing the adaptive response to redox, inflammatory balance, and, additionally, those genes that play a major part in DNA repair processes. Red laser irradiation enhanced the synthesis of procollagen, the expression of collagen, and the release of basic fibroblast growth factor.

Near infrared (NIR) (800-835 nm) light has two main types of chromophores which are intracellular water and cytochrome c oxidase that results in an increase in intracellular temperature. Thus, cell or tissue biological response to NIR irradiation is in part caused by a generated thermal effect. NIR, at the cellular level, activates cytochrome c oxidase (COX) the primary mitochondrial photoacceptor of light. This activation results in various cellular responses, including increased mitochondrial ATP production. [23] NIR light therapy has demonstrated increased mitochondrial metabolism, [24] with skin and gingival angiogenesis stimulation, [25] improvement in bone quality with stimulation of osteoblastic cell activity, [26] regeneration of muscle tissues. [27] Those increased ATP levels accelerates bone remodeling. This relates to elevation of metabolic activity, with accompanying angiogenesis, increasing the blood supply necessary for remodeling. [28] Additionally, wound healing is improved so incisions created during periodontal and oral surgery or traumatic injuries heal at a faster rate. [29] Pain is a common occurrence following surgery as well as during orthodontic treatment as aligners are changed or the fixed appliance is adjusted. NIR has demonstrated a reduction in pain and should be a consideration in those patients undergoing extractions, implant placement and periodontal procedures. [30,31] Additionally, reduction in post-operative swelling has also been reported and with a reduction in said swelling pain is also reduced. [32]

Both red and NIR have demonstrated an ability to accelerate orthodontic tooth movement by promoting alveolar bone remodeling on the compression side of the teeth. PBM using energy in the red range accelerated bone remodeling to a greater extent than NIR at an early stage. But, over time use of the two wavelengths together provided better results than using only a single wavelength. [33]

In-office PBM with the ATP38:

As outlined, different light wavelengths have various benefits to healing and regeneration depending on the tissue being treated and the condition present. The ATP38 Miracle system (Integrated Dental Systems, Englewood, NJ) provides 7 wavelengths (blue, green, yellow, red, deep red, NIR and infrared) adjusted to the frequency of the absorption peaks of the receptors of the cellular mitochondria of the various tissues being treated. The wavelengths used by the ATP38 Miracle provided a calibrated dosimetry defined by a restricted power protocol to biostimulate the cells. The application is controlled by a computer with preprogramed setting based on the application it will be used for, which sets the wavelengths and times they will be active through the unit. (Figure 2) As light scatters when leaving the source, significant amounts may not reach the intended tissue decreasing the effectiveness of the PBM. The ATP38, utilizes a semiconductor unlike other in-office units that keeps the light wavelength parallel, thereby applying the intended light and its power to the target tissue for better coverage and depth of penetration. The 4 illumination panels provide full coverage of the entire face and head thereby improving treatment potential without areas that may not receive PBM. (Figure 3) The ATP38 also utilizes a short wavelength which can be used for longer treatment periods with a high safety factor versus longer wavelengths and still have similar depth of tissue

penetration. Treatments are performed for less then 15-minutes and are able to reach the deepest layers of the area under treatment.

PBM treatment in-office with the ATP38 Miracle system provides the following benefits; increase in local blood circulation, increased wound healing, stimulation of regeneration of soft and hard tissues, muscle relaxation, temporary relief of joint pain (TMJ), minor arthritis or post-surgical pain relief and relief of muscle spasm associated with clenching and grinding.

Socket preservation:

A 40-year-old female presented with a severely broken down non-restorable mandibular premolar present. (Figure 4A) The residual root was atraumatically extracted and a PRF plug placed into the socket (Figure 4B) followed by suture placement to secure the plug. Accelerated wound healing with photobiomodulation of the PRF filled socket following extraction was performed. The patient was treated with the ATP38 utilizing Blue, green, yellow, deep-red, red, infra-red light simultaneously for 12 min at each session. Sessions were repeated every 48 hours during the 7 weeks following socket preservation. At 1-week post treatment and PBM sessions (Figure 4C) the area presented with a lack of soft tissue inflammation and sutures were removed. Post-operative examination at 2-weeks with continued PBM sessions demonstrated the appearance of advanced site healing (Figure 4D). A CBCT was taken, and the socket showed radiolucency where the PRF plug occupied the socket. (Figure 5A). At 3-months post-treatment a CBCT demonstrated dense fill of the socket with a blend with the surrounding bone (Figure 5B). Following flap elevation to expose the site, the PRF grafted socket presented as dense bone that blended with the surrounding host bone (Figure 5C). PBM has clinical benefits in the absence of the use of PRF (autologous blood concentrates) improving healing and site regeneration. (Figure 6)

Periodontal surgery

A 25 year-old male patient presented seeking improvement to her smile esthetics related to isolated recession on the right maxillary canine. (Figure 7A) Examination noted no other periodontal issues and there was no probing on the receded area and healthy gingiva was present. Treatment consisted of creation of a tunnel on the facial soft tissue with undermining the papilla on mesial and distal of the site to be treated to allow repositioning of the gingiva in a more coronal position. (Figure 7B) Connective tissue was harvested from the palatal area, which was placed into the previously elevated tunnel, which was then had the gingival tissue secured in a more coronal position to cover the receded tooth. (Figure 7C) The patient was treated with PBM twice weekly for 4 weeks to aid in acceleration of tissue healing. (Figure 7D) PBM with the ATP38 was performed using blue, green, yellow and red light for 5-minutes and 4-minutes of application simultaneously with deep red and NIR.

Orthodontics:

A 26 year-old male patient presented seeking improvement in the alignment of their anterior teeth for smile improvement. Examination noted minor anterior rotation in both arches with generalized good alignment in the posterior quadrants. Clear aligner orthodontic treatment was discussed and initiated. The patient returned for delivery of the 1st aligner and following insertion was treated with PBM with the ATP38 using red light for 6 minutes. Weekly (or was it bi-weekly?) the patient returned to be given the next aligner on the series and receive another PBM session. Alignment was achieved in an

accelerated manner following 8 aligners with a PBM session at each aligner delivery appointment. (Figures 8 and 9)

Facial esthetics

Wrinkle reduction and improvement in skin tone

A 53-year-old female presented with a complaint of sagging facial skin, wrinkles, and large pores. Treatment with the PAZ protocol incorporating PBM with the ATP38 was discussed with the patient and accepted. Treatment was performed with application of PRF and ozone therapy in 2 sessions, scheduled 2-weeks apart with 4 sessions of PBM between the PRF application sessions and following the 2nd PRF application. PBM with the ATP38 was performed using blue, green, yellow and red light for 5-minutes and 4-minutes of application simultaneously with deep red and NIR. At 1-month post initiation of treatment, the patients skin tone had improved with elimination of the wrinkles and pore size was no longer noticeable. (Figure 10)

Acne and skin blemish treatment:

A 23-year-old female patient presented seeking to address significant acne on the cheeks bilaterally. The patient expressed that she had been recommended medication to treat the acne and was seeking a more natural approach to treatment. Treatment using PBM with the ATP38 was discussed and accepted as treatment by the patient. The patient was treated with the PAZ protocol in 3 sessions 15-days apart over a month and a half treatment time. PBM was applied in 3 sessions between applications of PRF and ozone therapy over the treatment time. At each ATP38 PBM session blue, yellow, and red light was applied simultaneously for 4-minutes along with green, deep red and NIR for 3-minutes were applied. Following the planned treatment period, complete resolution of the facial acne was noted. (Figure 11)

Scar reduction:

A 49-year-old female presented seeking treatment to reduce a scar on her left cheek that resulted from an accident. A moderate sized horizontal scar was noted across the left cheek anterior to the zygomatic arch. The patient was recommended a single session with the PAZ protocol with 4 sessions of PBM with the ATP38. PBM was applied utilizing 5-minutes of application with blue, green, yellow and red light along with 4-minutes of deep red and NIR light. (Figure 12)

Dark circles around the eyes:

A 51-year-old female patient presented seeking an improvement in the dark circles around the eyes and sagging facial skin. The PAZ protocol was utilized which consisted of PRF placement in the affected facial areas, ozone therapy and PBM therapy with the ATP38. Treatment would be performed over a 1-month period of time with a 2nd application of PRF and ozone therapy 2 weeks after the initial session. PBM treatment was performed every 48-hours between applications of the PRF to the facial area. Treatment with the ATP38 utilized blue, green, yellow and red simultaneously

for 5-minutes along with deep red and NIR for 4 minutes at each session. Improvement in the skin tone, elimination of wrinkles and dark circles around the eyes were noticed after 4 sessions. (Figure 13)

Rosacea:

A 45 year-old female patient presented with rosacea on her forehead and bilaterally on the cheeks, seeking resolution of the skin issue. The patient was treated with micro-needling with PRF over the areas affected by the rosacea. This was followed 4 sessions of PBM using the ATP38 and a hydration skincare protocol was followed by the patient. PBM was applied using blue, green, yellow and red simultaneously for 5-minutes along with deep red and NIR for 4 minutes at each session. Resolution of the rosacea was noted following the 4th PBM session and remained resolved at a 6 month recall with no further PBM applications provided. (Figure 14)

Hair regrowth:

A 56-year-old male presented with the complaint of thinning hair at the crown of his skull and seeking treatment to correct the balding issue. The PAZ protocol was discussed with the patient and treatment was accepted which would consist of 2 sessions, 4 weeks apart of PRF placement and ozone treatment with weekly PBM sessions over a 2-month period. ATP38 treatment consisted of 3 minutes of application of the green, yellow, red, deep red and NIR light with 2-minutes of blue light application at each session. The PBM sessions were performed weekly. Hair fill was noted to be starting after 4 weeks following the 1st session of the PAZ protocol and significant follicle fill was noted after the 2nd session with the protocol. (Figure 15)

Conclusion:

PBM, also referred to as LLLT (low level laser therapy) has increasingly demonstrated to improve healing and regeneration in soft and hard tissues. Its applications include as outlined facial esthetic procedures, orthodontic acceleration along with improvement in extraction socket fill and implant osseous acceleration with regard to stability and bone quality improvement. Extensive documentation has shown that PBM amps up the body's responses improving healing and regeneration and may be considered as an adjunct to other treatment being offered to improve clinical outcomes.

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Figures:

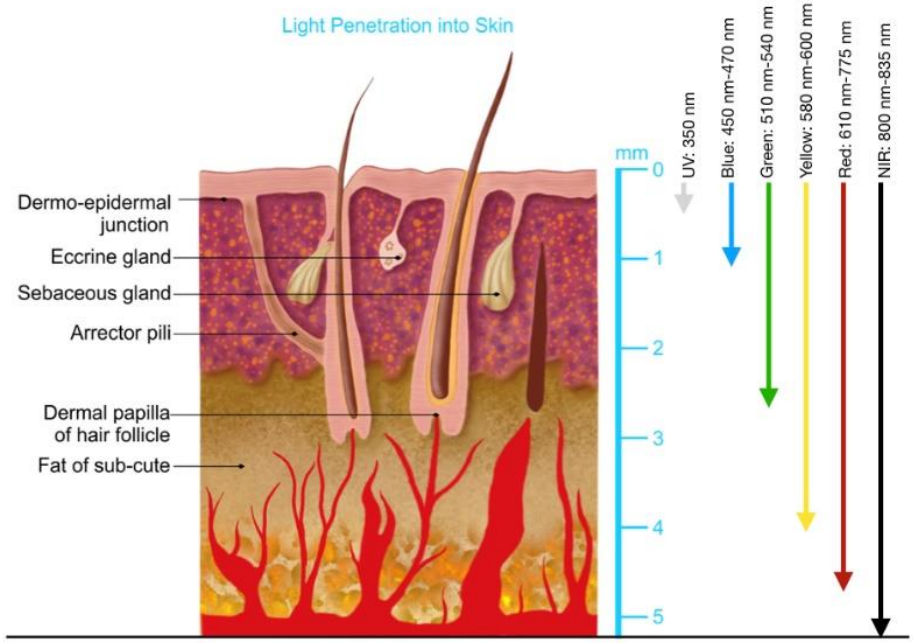

Figure 1: Depth of penetration for the various wavelengths

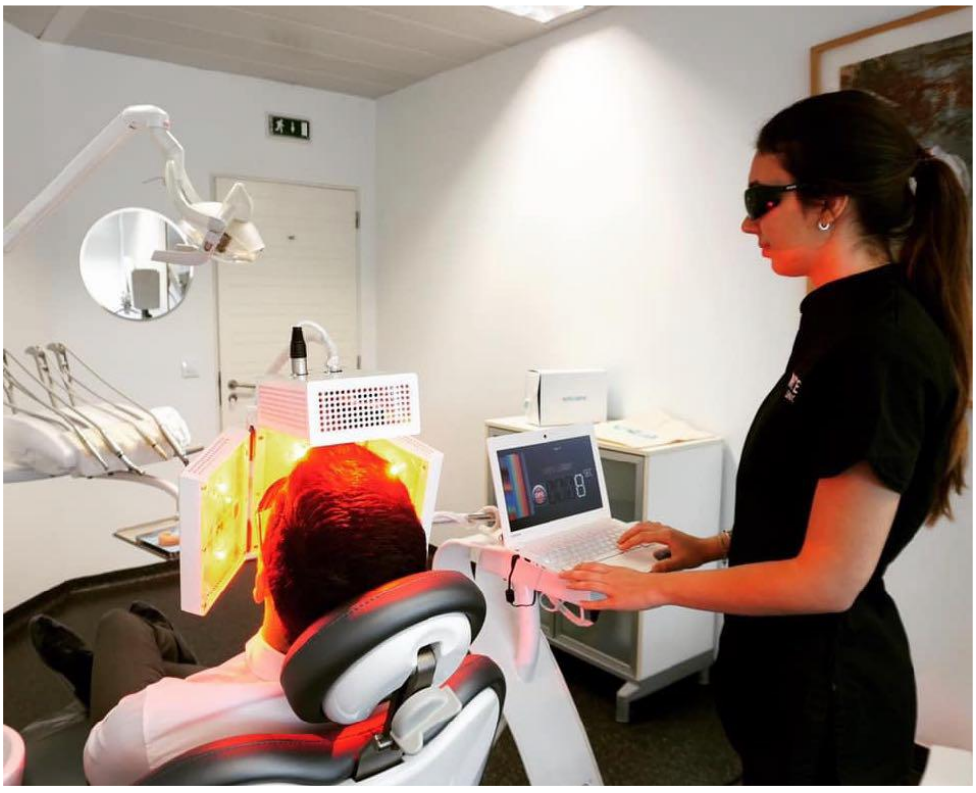

Figure 2: The ATP38 positioned for use on the patient and wavelength irradiation controlled by the unit's computer system.

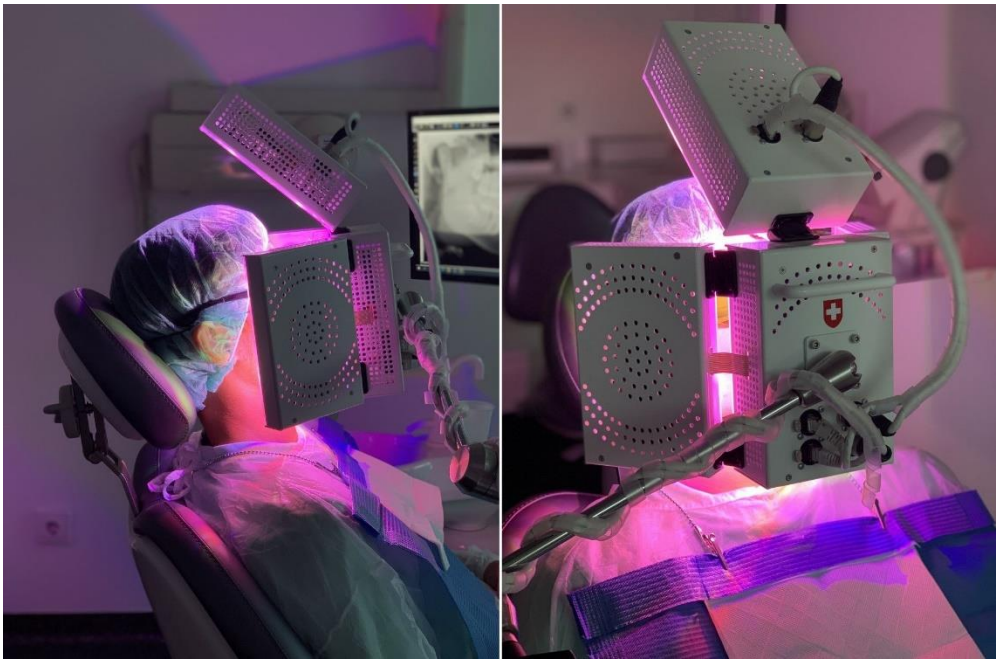

Figure 3: ATP38 is positioned to expose the entire facial region to the selected wavelengths for the procedure being utilized providing maximum exposure to the PBM.

Figure 10: Female patient presented with age related sagging skin and wrinkles around the eyes (left) and following use of the PAZ protocol with PRF, ozone and PBM with the ATP38 after 4 sessions demonstrated tightening of skin tone and elimination of the wrinkles around the eyes (right).

Figure 11: An adult patient presented with complaint of unesthetic areas on her cheeks bilaterally that she had been unable to resolve with traditional skin cleansing methods (left) and following PBM treatment with the PAZ protocol demonstrating complete resolution of the acne (right).

Figure 12: Patient resented with a scar on the left cheek (left) with resolution of the affected skin area with 4 sessions of PBM with the ATP38 over a 1-week period of time (right).

Figure 13: Female patient presented with complaint of dark area under the eyes bilaterally (left), treatment with PAZ protocol corrected the esthetic issue with complete resolution after 4-weeks (right).

Figure 14: Female patient with Rosacea on the forehead and bilaterally on the cheeks (left) with 4 sessions of micro-needling with PRF and PBM treatment with the ATP38 unit (middle) and continuance of resolution as evidenced at 6 months with no additional treatment (right).

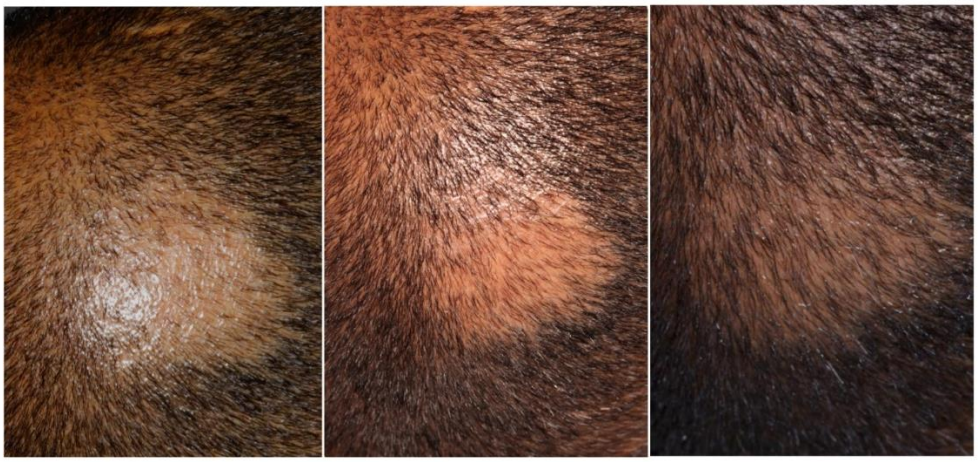

Figure 15: A male patient presented with the complaint of a balding area at the crown of his skull (left), 4 weeks after use of PRF and PBM with the ATP38 demonstrating some hair regrowth in the area (middle) and 4 weeks following a second session with PRF and PBM demonstrating hair follicle fill of the bald area (right).