

The use of Nd:YAG laser in treatment of superficial vascular and pigmentary lesions

استخدام ليزر Nd:YAG لمعالجة الوحمات الوعائية السطحية والصبغية

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Abstract

In this work, Nd:YAG laser with two wavelength (1064,532)nm was used in treating vascular (port wine stain, hemangioma ;and Telangiectase). Also Nd:YAG laser was used in tattoo treatment and the results achieved is best than by using (KTP,PDL and Ar) laser. This process is occurs via absorption laser beam by skin layers, especially surface skin layer which is useful in the cosmetics surgical. There are different properties related with skin layer such as thermal diffusion and thermal relaxation time, the later is higher than the time of laser puls and this cause cooling to one –half without according thermal diffusion in normal (healthy) skin region.

Nd:YAG laser can absorbed deeply and this observed when it used to remove the deep pigmentation, in compare with other laser types which absorbed only by the surface of skin layer because of low power , wavelength , frequencies and intensity in compare with Nd:YAG laser.

Keyword: Nd:YAG laser, wavelength, treatment of superficial, superficial pigmentation, lasers.

الملخص

اعتمد هذا البحث على استخدام ليزر Nd:YAG بطولين موجين (1064,532nm) وقد استخدم كمعالجة لعدة انواع من الوحمات (port wine stain, Hemangioma, Telangiomas) . كما ويستخدم ليزر Nd:YAG في علاج (تاتو) حيث تم الحصول على نتائج افضل عند مقارنته مع انواع الليزر الاخرى منها (Ar,PDL,KTP). حيث ان العملية تحدث بواسطة امتصاص شعاع الليزر بواسطة طبقات الجلد وخصوصا الطبقة السطحية ومفيد من ناحية الجراحة والتجميل . حيث ان الصفات المختلفة لها علاقة مع طبقات الجلد والانتشار الحراري وزمن الاسترخاء الحراري . ان قيمة الزمن الحراري يجب ان تكون اكبر من زمن الليزر وفي هذه الحالة تحدث البرودة الى النصف بدون حدوث الانشار الحراري على المناطق السليمة من الجلد. ان لليزر Nd:YAG قابلية امتصاص عميقة كما ويستخدم لازالة التصبغات الجلدية بمقارنة مع انواع الليزر الاخرى التي لها قابلية امتصاص سطحية في طبقة الجلد بسبب القدرة الواطئة ، الطول الموجي ، التردد، الشدة مقارنة مع ليزر Nd:YAG.

المفاتيح: ليزر Nd: YAG ، علاج الوحمات الوعائية السطحية، الوحمات الصبغية، العلاج بالليزر.

Introduction.

There are less cases of purpura, rankles, coverings, and modifications in pigmentation with the Nd:YAG laser accurately since the 1064nm wavelength is ingested less viably by the endogenous melanin. The to begin with photodepilation gadget promoted in the joined together states utilized this wavelength , but in the ultra- brief beat or Q- exchanged mode (beat length in the extend of nanoseconds). In spite of giving palatable starting result [1, 2]. They demonstrated incapable in accomplishing long – term diminishments in hair development. Gadgets right now utilizing this wavelength apply beat length in the run of milliseconds (long- beat Nd:YAG), closer to the TRT of the hair follicle. A few thinks about have appeared the adequacy of long – beat Nd:YAG laser in long – term hair lessening, over all in patients with dull phototypes [3,4].

Melanin exhibit bring down retention coefficients for this wavelength than those of the lasers. This lessened retention implies a lower danger of consumes and ensuing optional hypo-and hyperpigmentation or scarring in high phototypes or tanned skins. Nonetheless, given that melanin

is additionally the chromophore of the objective tissue (the follicle), this lower absorption coefficient suggests the requirement for higher fluencies than those utilized at other wavelength if powerful warming of the follicular structure is to be accomplished. Albeit late examinations don't indicate huge contrasts in viability between the wavelength of the lasers specified before and the Nd:YAG laser, the primary inadequacy is that photodepilation strategies embraced at this wavelength are for the most part more agonizing than the others. This issue can somewhat be settled by the utilization of topical analgesics or extra skin cooling frameworks. Another issue is that the related agony limits both spot size and terminating recurrence, implying that treatment sessions with this wavelength are for the most part longer in examination with alexandrite or diode lasers.

1. Nd: YAG Laser.

The close- infrared lasers, such as the 1064nm neodymium: yttrium aluminum garnet (Nd:YAG) laser, are not perfect for treating PWS (Harbour Wine Recolor) due to particular harm to courses Or maybe than veins. Be that as it may, the 1064nm laser has a higher assimilation coefficient of blood compared with the encompassing dermis, which gives treatment selectivity of more profound blood vessels ($\geq 2\text{mm}$) , making it a way better treatment alternative for hypertrophic PWS than PDL [5]. Warm damage of more profound blood vessels may lead to corruption of the encompassing dermis and increments the hazard of scarring compared with treatment with the PDL. This may be clarified by the fractional change of oxyhemoglobin to methemoglobin after photocoagulation by 1064nm Nd:YAG laser illumination, which leads to expanded retention by laser fluences and a exceptionally soak fluence reaction bend. Quick alter in skin reaction may be dodged by utilizing underneath the least purpuric dosage [5].

2. Q-Switching

In addition to their categorization by wavelength, lasers can be divided into continuous wave (CW) or pulsed (P). A CW laser delivers a steady stream of light that is measured as average power in watts or kilowatts. And a pulsed laser delivers a very short but intense light emission followed by a period of no light. If the laser is repetitively pulsed, the pulse repeats itself on a regular basis. The time between the pulses is referred to as the inter pulse period and the length of each pulse is called the pulse duration. So, the number of hertz (Hz) represents the number of pulses emitted per second and the length of the pulse duration is an important characteristic of any pulsed laser/light device. Pulses lasting a few millisecond [10-3] are generally characterized as long pulses. Nanosecond [10-9] pulses are considered short. Q-Switched Nd: YAG laser pulses are typically [3-7] nanosecond in length in figure (1) [6].

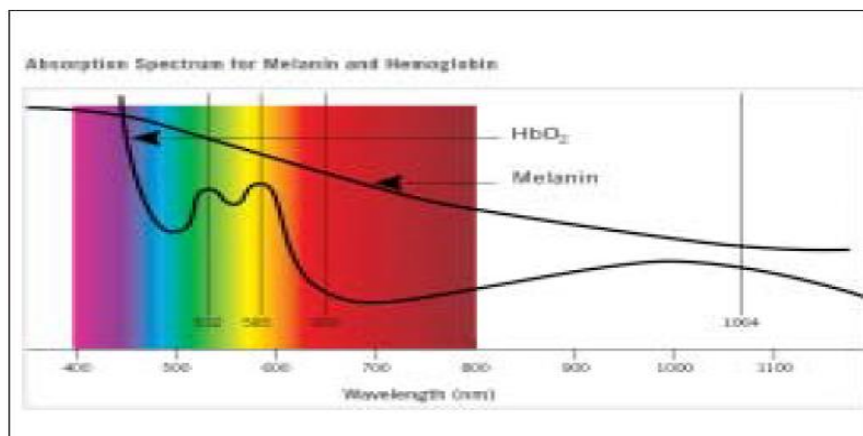


Fig. (1) Absorption spectrum of melanin and hemoglobin.

3. Selective photo- thermolysis

Selective photo – thermolysis term was introduced by Anderson and Parrish [7]. That clearly shows to the objective of the particular pulverization of a tissue structure by an increment in temperature initiated by a light source. There are three critical parameters to be taken into account in accomplishing specific photothermolysis

3-1 Suitable wavelength

The wavelength must be ingested by the target chromophore and must have the capacity to enter to the profundity at which the chromophore is found.

3-2 Pulse duration

The span of presentation of the chromophore to the light shaft must be lower than its warm unwinding time (TRT). The (TRT) is the time it take for the temperature of the chromophore to reduction to half of pinnacle following introduction to radiation. The chromophore cools by warm dispersal to the encompassing tissue, implying that the TRT truly demonstrates when the radiation connected will initiate a brought temperature up in the encompassing tissue by transmission of the warmth created inside the objective region. As we intend to maintain a strategic distance from harm to the encompassing tissue, we should guarantee that the beat does not surpass the TRT. The TRT is for the most part specifically corresponding to the measure of the objective tissue.

3-3 Sufficient fluence

The energy density administered in the exposure time (measured in J/cm^2) must be sufficient to result in destruction of the target tissue.

4. Three dimensional fractional skin treatment

Upon light with an enough brief laser beat, vitality is stored into the retaining structure some time recently a critical sum of warm can be conducted to the encompassing tissue. The temperature rise in an optically and thermally homogenous structure is specifically relative to the ingested warm, which is itself corresponding to the laser familiarity (in J/cm^2) conveyed to the target. In case a noteworthy division of the kept warm diffuses absent from the retaining structure amid laser presentation, the crest temperature is decreased, impeding the spatial selectivity of the treatment indeed in case the wavelength gives specific assimilation of laser vitality. The choice of an suitable laser beat length is subsequently foremost. Laser beats of length t_p that are altogether brief than the target warm unwinding time (τ) will cause a maximal temperature rise in a target structure for steady beat vitality. The unwinding time, τ , speaks to the time interim in which the sufficiency o

In a simple way, the thermal relaxation time (TRT) depends on the diameter of the target structure (d), and the thermal diffusivity of skin ($0.11mm^2/s$) as $\tau = d^2/(20\alpha)$

An exact formula would depend on the shape of the skin structure [8].

Based on the over contemplations it is expected, for the leftover portion of this paper, that specific warming of a skin structure happens when the beat length is shorter than the unwinding time τ by a figure of two. Figure 1 appears the reliance of the negligible estimate (d) of the flaw or hair that can be selctively warmed by a laser beat of term t_p . In agreement with Figure (5), imprisonment of laser vitality inside littler structures requires continuously shorter beat lengths. For structures littler than $100\mu m$, beat lengths less than 1ms must be utilized.

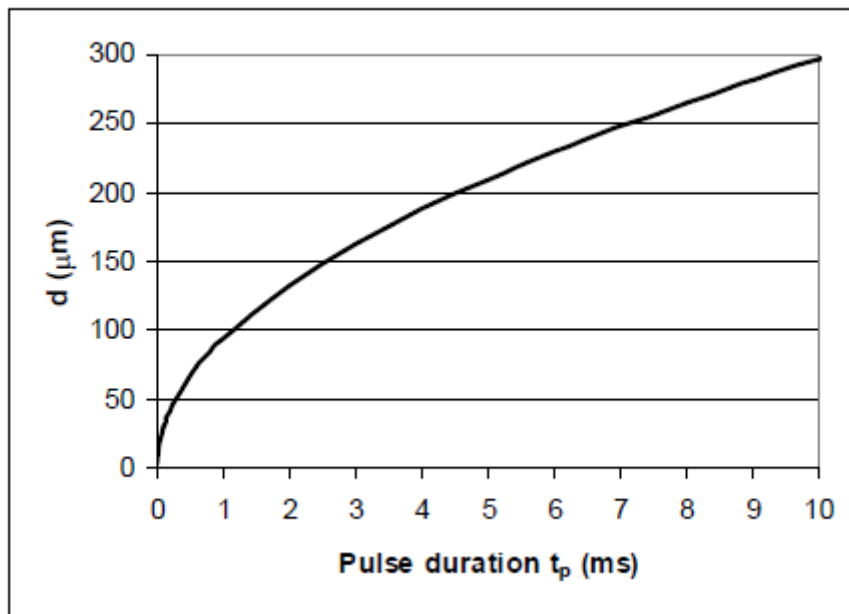


Figure (2) Minimal size (d) of a skin structure as a function of laser pulse of duration t_p .

In as much as beats altogether shorter than τ give the heights temperature , it would appear that the finest approach would be to utilize greatly brief beats ($t_p \ll 50\mu\text{s}$) to guarantee warm control in skin structures of all sizes , but this is not the case. Explosive vaporization of specifically retaining hemoglobin can happen when beats shorter than $10\mu\text{s}$ are utilized at tall laser fluencies [9]. Essentially, epidermal melanosomes can be non – consistently overheated amid tall fluence laser beats underneath ($25\mu\text{s}$) [10]. The most secure and most compelling beat terms for negligibly obtrusive skin restoration are in this manner in the $100\text{-}1000\mu\text{s}$ extend.

When Nd:YAG laser($1064,532\text{nm}$) beats in the ($0.1\text{-}1.0\text{ms}$) extend are utilized, little skin blemishes , in homogeneities and hair follicles are specifically warmed all through the lit up skin tissue (fig.3). Fragmentary islands of thermally influenced skin structures that are shaped in the three dimensional skin tissue.

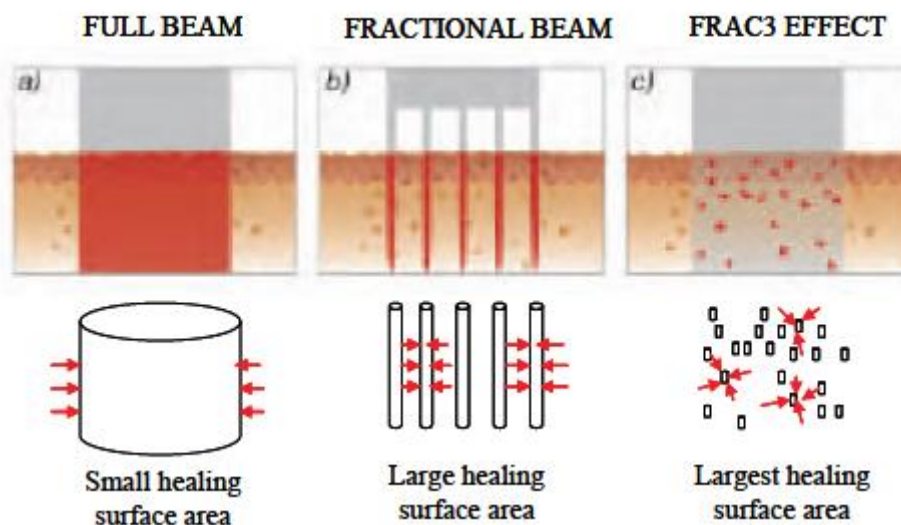


Fig. (3) Standard uniform laser treatment. (b) Standard two dimensional fractional treatment. (c) Novel self – induced three – dimensional.

5. Laser tissue interaction

Light is electromagnetic radiation that covers a wide range of wavelength (from x- beam to radio waves). When we illuminate tissue – in this case the skin – with a light source, a few noteworthy physical marvels happen (fig.4). Since of the distinction in refraction coefficients between discuss and the cornel epithelium, a few of the radiation is reflected. Another portion of the radiation transmitted or entering the tissue gotten to be scattered. At last, the radiation that reach the target tissue be retained by the structure. Any target tissue or structure must contain a substance or particle with the fitting physical and chemical characteristic to assimilate this radiation. A atom that retains a given wavelength is known as a chromophore. All of the therapeutic applications of light sources are built upon the essential physical guideline of retention.

Ingestion of the radiation by the chromospheres must happen all together for a natural response to happen. The vitality gave in the radiation consumed by the objective tissue experiences a change with a few conceivable results: photograph warm (increment in temperature), photomechanical (warm development delivering sound waves), or fluorescence (outflow of photons at another wavelength). In photograph depilation, a photograph warm impact is looked for so as to raise the temperature of the follicular structure and along these lines crush it .Each chromophore has the ability to ingest certain wavelength. This is a critical reality as it is the retention profile of the chromophore that will figure out which wavelength must be utilized to treat it. Along these lines need to know at which wavelength the assimilation pinnacles of every chromophore happen. Melanin is the objective chromophore in photodepilation. This intracellular color is portrayed by high retention coefficient for all wavelength in the obvious range yet in an opposite connection to the wavelength, which means the ingestion coefficient diminishes as the wavelength builds (Fig.5). The wavelength of the radiation utilized is essential not just in light of the fact that it decides the specificity for a given chromophore, yet additionally on the grounds that infiltration profundity is needy upon this. At wavelength inside the low retention record of water (400 to 1000nm), as the wavelength increment, dispersal inside the dermis diminishes, expanding the profundity of infiltration at the wavelength (Fig 6). In spite of the fact that wavelength is the fundamental factor deciding the profundity of the radiation utilized, the extent of the objective zone or spot is another parameter that may likewise force confinement: the bigger the detect, the more profound the entrance at any given wavelength (Fig.7). This is an aftereffect of the cone shaped constriction of the light emission because of dispersal.

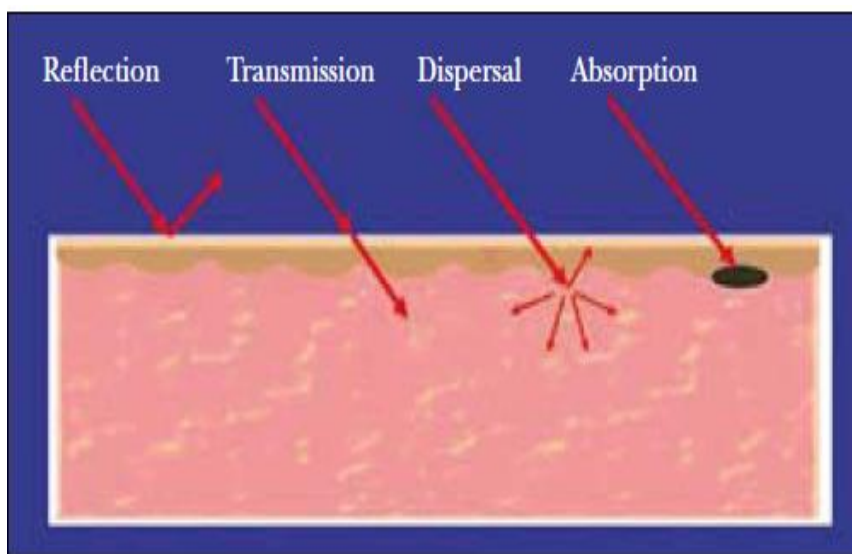


Fig. (4)Diagram showing the different physical phenomena that occur when skin is irradiated with a light source.

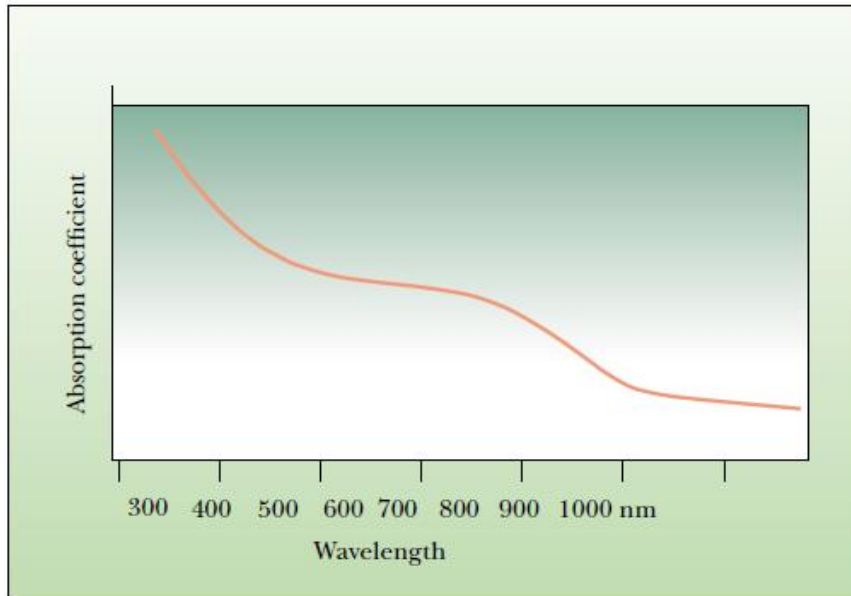


Fig. (5) Diagram showing the relationship between wavelength and the absorption coefficient of melanin.

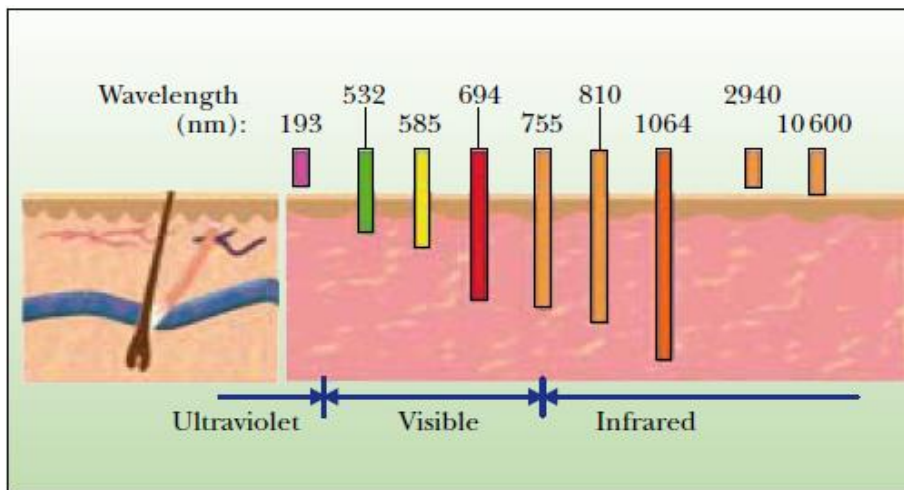


Fig. (6) Diagram showing the relation between wavelength and capacity for penetration into the skin.

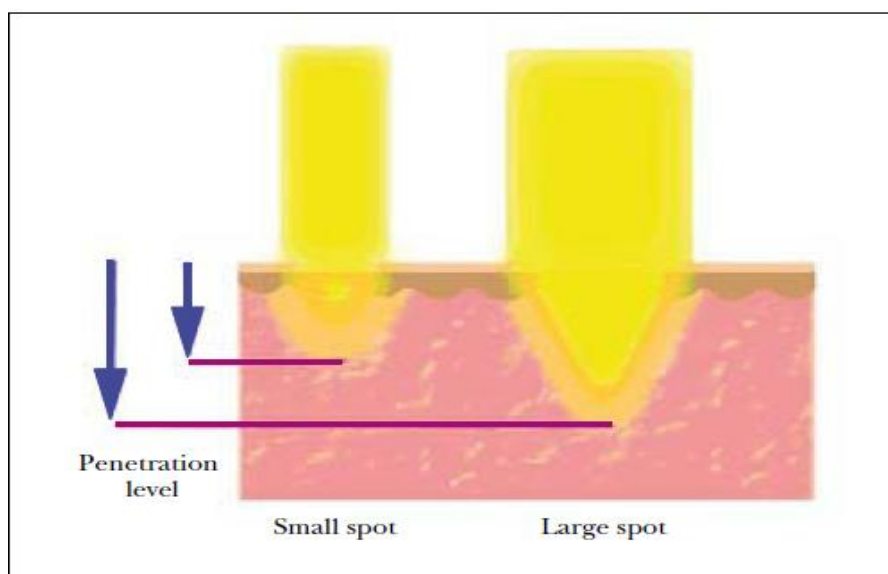


Fig (7) Diagram showing the relationship between spot size and the capacity for penetration into the skin by the same given wavelength.

6. Laser for vascular skin lesions

Telangiectase: are extremely commonplace in today's adult population, occurring in at least 15% to 20% of the population. These are small dilated vessels with diameters between 0.1 and 1.0 mm. Many cutaneous disorders are associated with an increase in telangiectases, most commonly acne rosacea. Telangiectases. Most commonly acne rosacea.telangiectases can also be found in association with surgical scars. Treatment of facial telangiectases is one of the most commonly used devices used to treat telangiectases include the 532nm and 595nm lasers and IPL devices with cutoff filters between 500 and 1400nm. Typical result from treatment with the PDL can be seen in fig.8.



Fig. (8) A typical patient before and after 3 treatments with a PDL (10mm spotsize, 9.0-10 J/cm², 10-20 ms pulse width with cryogen spray cooling).

Traditionally, vascular lesions have been treated with PDL at purpuric pulse durations with excellent results despite the 7 to 10 days of bruising. To prevent bruising, previous work had shown that multiple passes and / or pulse stacking could lead to improved vessel clearance, but such techniques were time consuming and led to longer, uncomfortable treatment sessions [11,12]. Subpurpuric fluence settings with a 10mm spot size range from 6.5J/cm² to 7.5J/cm² with a pulse duration of 6 to 10 milliseconds. [11,12]. Consumer pressure has driven industry to create devices that can lead to excellent clearance of vascular lesions within the context of nonpurpuric "zero-downtime" treatments. As mentioned previously, a novel PDL with an advanced micropulse structure is now available. single – pass treatment of telangiectases is now possible with a macropulse duration as short as 10ms [13]. In the context of overall photorejuvenation encompassing treatment for vasoverall and pigmented lesions a recent comparative, multiple treatment, split-faced study found the novel PDL with a compression handpiece to be comparable to high fluence IPL. In this study, vascular lesions improved to a greater degree than IPL, but treatments took longer, were more painful and resulted in more posttreatment edema. [14].

Hemangioma: Hemangioma are the most common benign tumors of childhood. [15]. these are tumors and not malformation or hamartomas, such as a PWS, in that they are characterized by an initial phase of proliferation that is variably followed by a period of slow involution. They are positive for a glucose transporter that is highly expressed in placental tissue. They are 10 times more common in children of women undergoing chorionic – villus sampling during pregnancy. [16] Complete regression is usually observed in time. Nevertheless, depending on their size, clinical behavior (e.g growth, ulceration, scarring), and location (eg, periocular, laryngeal distribution), they may have devastating consequences. Lasers are commonly used to treat hemangiomas for 3 distinct indications treatment of the proliferative phase, treatment of ulcerations, and the treatment of residual telangiectases after involution is complete [15]. Various devices can be used to

treat hemangiomas, including the PDL, Nd:YAG , alexandrite, and KTP-based platforms. Results seen after multiple Nd:YAG treatment are shown in fig.(9).



Fig. (9) Use laser Nd:YAG

The most commonly used device is the PDL which is generally regarded as the treatment of choice for superficial lesions .it does not penetrate as deep as the longer wave length based platforms but has special utility in the treatment of photocoagulating ulcerated lesions leading to improved reepithelization and decreasing pain [17].

Thicker, deep lesions may have an increased deoxyhemoglobin ratio, thereby shifting the absorption curve of these lesion to the near -IR range (700-1200nm). The more deeply penetrating 1064nm and 755nm lasers are less commonly used in the treatment of deeper hemangiomas and should probably only be performed by experienced laser surgeons because of the increased risk of deep thermal injury and the subsequent scarring that can result. Oxyhemoglobin strongly absorbs 532nm, but when applied transcutaneously, its relative poor penetration makes it a poor option when treating hemangiomas. The 532nm platform has been shown to be inferior to the PDL in treating hemangiomas[18]. Although uncommonly used, intralesional bare fiber KTP treatment of hemangiomas has been reported as an option when treating the deeper components of cutaneous hemangiomas [19].

Port wine stain: In contrast to hemangiomas, are localized defects of vascular morphogenesis, probably caused by disruption in monitoring embryogenesis and vasculogenesis[20]. Most if not all congenital; however. There are reports of antecedent trauma playing a role [21]. Composed of ecstatic capillary malformation in the upper layers of the dermis, PWS are also associated with some genodermatoses such as sturge- Weber and Klippel – Trenaunay syndromes. PWS usually grow in proportion to the child and may thicken with age. In addition, associated structures such as the lips, gingivae and tongue may enlarge to topographic dysmorphism.

The PDL is the most commonly used platform in the treatment of PWS. Commonly used fluencies used in treating PWS are 4 to 12 J/cm² with pulse widths of 1.5 to 10ms with a 7mm spot size. Newer devices have larger spots and, in the future, may prove to be more effective because of their increased depth of penetration. Larger spot sizes generally require reduction in fluencies; however, with new micropulse advances, there very well may be less reduction than expected to attain the desired clinical outcomes of deep purpura without significant graying. Multiple treatments are the rule and it is generally accepted to treat the superficial vessels first before targeting the deep, more recalcitrant ones [22]. The result of multiple treatment with the PDL can be seen in fig. (10). However, not all PWS will clear with PDL treatment. Most studies show that less than 20% of PWS can be completely lightened , although 70% will lighten by 50% or more whereas 20% to 30% respond poorly[23,24] certain PWS may respond poorly as the result of multiple factors, including

(1) inadequate depth of penetration (2) inadequate conduction of laser – induced heating from centrally situated hemoglobin to vessel walls (3) inadequate blood volume (not enough chromophore to absorb/ transmit heat) to destroy smaller vessels , and (4) inadequate fluence entering deeper capillaries due to obstructive fibrosis that was caused by previous treatment of superficial vessels. The last point mentioned argues against the commonly held dictum of treating the superficial vessels first [22].

Treatment earlier in life may lead to fewer treatments and may improves outcome [24, 25]. A recent study has suggested that frequent, high energy pulsed – dye laser treatments are safe and high effective in improving facial PWS in infants ≤ 6 months of age and that they should be referred for PDL treatment during early infancy [26].

Less commonly used modalities used to treat PWS include IPL, KTP and Nd: YAG – based platform [27-29]. However , when used solely, all have generally poorer side- effect profiles than the PDL due to high melanin absorption (IPL , KTP) or increased depth of penetration with a inherent risk of scarring (Nd:YAG) . New technologies, such as sequential varying wavelength have been applied with promising results [30, 31]. With such devices such as the synergy multiplex (cyanosure Inc, westford, MA), a 595nm pulse is delivered and followed by 1064nm pulse. In this way, methemoglobin is formed in the vessel from the initial pulse which has a significant absorption peak near 1064nm, thereby increasing the absorption of laser energy leading to effective treatment of typically recalcitrant lesions.



Figure (10) port wine stain use laser Nd:YAG compare laser PDL

Poikiloderma of civatte: Poikiloderma of civatte is a ruddy sun- induced dyspigmentation disorder with a prominent vascular component. The typical tetrad of features include hyper- and hypopigmentation, telangiectases and atrophy. It present in the fifth to sixth decades of life and is histologically characterized by solar elastosis, dilated superficial papillary vessels with an trophic epidermis featuring irregular epidermal melanin distribution [32]. Many lasers, including the KTP, PDL, and IPL have been reported as effective owing to the lesions rich vascular and melanin based chromophores [33, 34]. Great care and conservative settings are required when treating this condition, as is the case in treating any chronically bronzed skin with lasers as severe depigmentation has been reported [35]. Most recently, there has been report of using a 1550nm. At pulse energy of 8mJ with a final density of 2000MTZ/cm². These settings lead to approximately 18% of the treated area being photothermolysed. This device uses water as its chromophore and nonspecifically targets the dermal vasculature and possibly targets the water component of blood within the vessels fig (11) [36].



Figure (11) poikiloderma of civatt

7. Application laser Nd:YAG

Pigmented injuries: - While the epidermal injuries react best to 532nm (recurrence multiplied Nd:YAG) the dermal injuries are superior treated with 1064nm . Q-Switched lasers are the gold standard for treatment of tattoos.

1. Lentigines:- normally 1-2 sessions are enough to clear lentigines at 532nm .However there is risk of hypo/ hyperpigmentation, so avoidance of sun exposure for 4-6weeks post laser is very important.
2. Cafeaulait macules: - these again can be treated effectively in 1-2 sessions, but recurrence is common which requires multiple treatments.
3. Freckles: - Response is same as for lentigines. Even though very effective, risk of dyspigmentation exists.
4. Dermal pigmented lesions: - Nevus of Ota, Nevus of Ito, Mongolian spots, Horis nevus. And other flat pigmented birthmarks respond well at 1064nm.

A. Medium depth nonablative skin resurfacing

Frequency doubled 532nm Q-switched is a well- built up innovation for treating photoaging. When used at lower fluences with a larger spot size, it is a medium depth laser peel, with less downtime and high patient satisfaction. So, due to the risk of postinflammatory pigmentary change in Indian skin, it should be used only after a test patch and adequate sun protection advised to the patient.

B. Melasma

High – energy pigmented selective laser , 694nm ,Q-switched ruby laser , 755nm Q-switched alexandrite laser , 532nm frequency doubled Q-switched Nd:YAG laser, and 1064nm Q-switched Nd:YAG laser had been studied for treatment of melasma with poor result . Normal skin color was rarely achieved. Epidermal melasma responds better and faster than dermal/mixed melasma. Complete clearing of lesions may be expected in more than 50% of case of epidermal melasma. Complete clearing of dermal / mixed melasma may be seen in about 30-50% case, while the remaining case will show moderate improvement. Postinflammatory hyperpigmentation and rebound melasma are dreaded complication that may occur in the individual with sensitive skin. Lower energy and fewer repetitions are adequate to produce marked improvement. Improvement will need to be maintained by repeated treatments. However, recurrence is common in melasma.

C.Tattoos

Though Q-switched ruby and Q-switched alexandrite lasers have been earliest lasers for tattoos, Q-switched Nd:YAG 1064nm , due to its longer wavelength , higher fluence, and shorter pulse, has emerged as a better laser for black and dark blue/ black tattoo pigment. The textural change, scarring, and hypopigmentation of earlier lasers are remarkably low. However for colored pigments, use of multiple wavelength is mandatory. Response to Q-switched 1064nm depends on the type of tattoo [37].

1. Professional tattoos: Most of them such tattoos have even distribution of ink, mainly in subcutaneous tissue.
2. Amateur tattoos: - it is easy to remove, but in some cases, if the ink is at deeper level, a few extra sessions could be required.
3. Cosmetic tattoos: - this tattoos like eyebrows, and eye and lip line are mostly made of iron – based inks. This can sometimes oxidize turn black. So, a test patch must be given.

Conclusion

Laser Nd:YAG (wavelength 1064,532)nm depend of the kind of laser case lesion (port wine stain ,tattoo, hemangioma) used Nd:YAG (1064nm) in the use state deep, wavelength (532nm) in the use state superficial. The result fluences (25,30,40J/cm²),tip (3mm) , pulse(20,25,30sec) ,session (6) is become is best with Q.S Nd is very good result for compare between this result PDL (pulsed dye laser)(550-800nm). There is no side effect (burns, risk) on the patient.

Result and Discussion

From the interaction of the laser Nd:YAG (=1064) with fluence range from 0-20(j/cm²) against (1-14 H²) there is change in the shape of graphs depending on the kind of laser and kind of tattoo as shown in Fig(1).

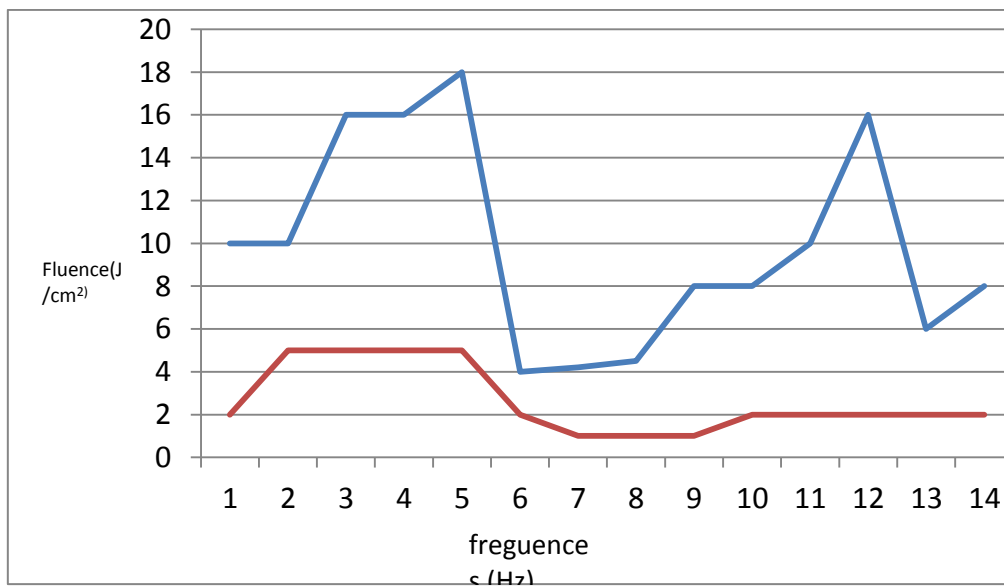


Figure (1) laser Nd:YAG use treatment tattoo, relation between (fluence(J/cm²)) (frequencies (Hz)).

A using of laser for pigmentation, the relation between fluence J/cm^2 against frequency as shown in Fig (2).

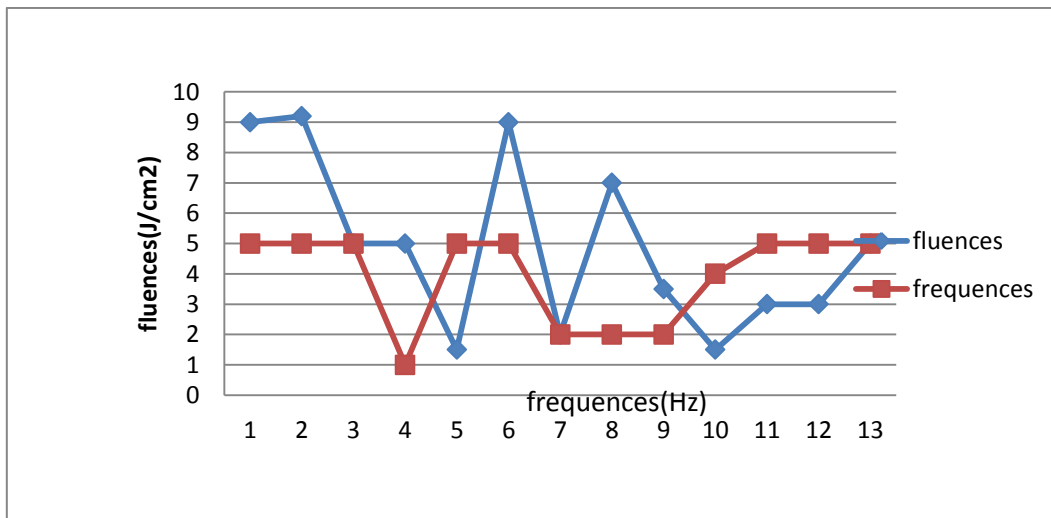


Figure (2) laser Nd:YAG use treatment pigmentation , relation between (fluence(J/cm²)) (frequencies (Hz)).

Fig (3) show the treatment Nd:YAG for port wine stain, the relation between fluence (J/cm^2) and Tip of head pice (mm)

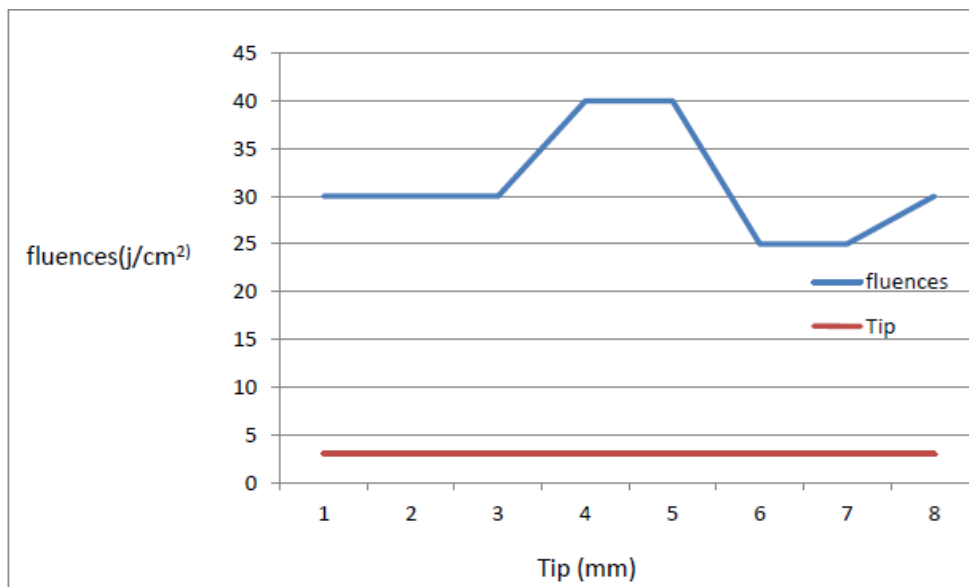


Figure (3) laser Nd:YAG(1064nm) use treatment port wine stain, relation between (fluence(J/cm²)) (Tip(mm)).

From Fig (4) there is the diameter of Tip not effect on the fluence

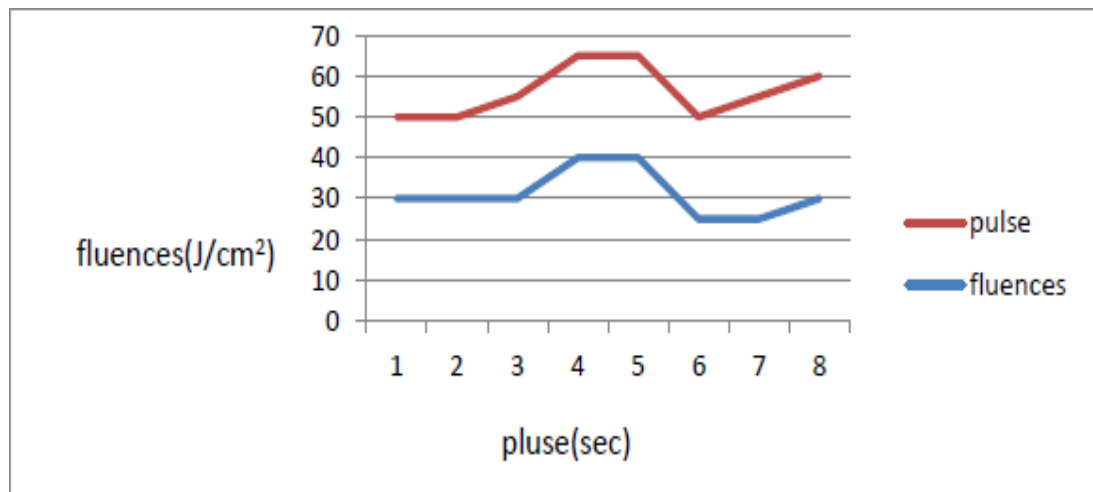


Figure (4) laser Nd:YAG use treatment tatto, relation between (fluence(J/cm2) (pluse(sec)).

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