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Human Skin Wound Welding Using 980 nm Diode Laser: an in Vitro Experimental Study

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Abstract: Laser assisted skin wound closure offers many distinct advantages over conventional closure techniques. The objective of this *in vitro* experimental study, carried out at the Institute of Laser for Postgraduate Studies/Baghdad University, was to determine the effectiveness of 980 nm diode laser in welding of human skin wounds. Multiple 3-4 cm long full thickness incisions in a specimen of human skin obtained from the discarded panniculus of an Abdominoplasty operation were tried to be laser welded using a 4 mm spot diameter laser beam from a 980 nm diode laser at different laser parameters and modes of action. The tensile strength at the weld site was analyzed experimentally. Although laser assisted wound welding did actually happen at many laser parameter settings, it was not strong enough to be clinically useful in living human beings. Despite the 980-nm diode laser system has proved to be an effective way of wound welding but it the weld was of low tensile strength to withstand living patient normal daily activity and movement. It can really shorten the operative time required to close a wound if proper laser parameters were used among an endless effective combinations of parameters. Further future studies are highly recommended on live human beings.

Introduction

Surgery is the science and art of cutting and joining. Conventional methods are currently used for wound edge joining such as surgical sutures, adhesive tape, staples, clips, tissue glue and adhesives. Recently, laser skin welding has been added and it's claimed to be faster, watertight, avoids a foreign-body reaction, minimal inflammation and tissue trauma, and consequently reduced scar formation and improved cosmetic results (Bassam 2009, Wider 1991, Charles 2007). It may even lead to a faster healing since laser energy used may also actually stimulate the tissue healing process (Lon 1999). This technique is becoming important in many surgical specialties, including urology, cardiothoracic surgery, plastic surgery, and neurosurgery. The method is used especially in instances when stapling or suturing is difficult. However, collateral thermal injury, laser device cost and variability of results has prevented its wide clinical use until now. In experimental animal models, it showed good results but there is paucity of studies that has been published on use of this modality in human beings (Abergel 1986, Fried 2000, Mia 2001).

A 980-nm diode laser has been chosen in this study because it has the advantage of emitting a laser that has a relatively high absorption peak by water and hemoglobin while the absorption coefficient of melanin for 980-nm laser is less than the absorption coefficients of it for 780- and 815-nm diode lasers leading to even more penetration of laser energy to deeper skin layers (about 3-4 mm) (Murat 2006).

The objective of this *ex vivo* study is to evaluate the effectiveness of 980nm diode laser in laser human skin wounds welding experimentally and to determine whether it would be of a sufficient initial tensile strength to be more applicable clinically in future in vivo studies.

Materials

All procedures and experiments have been conducted at the Institute of Laser for Postgraduate Studies during the period from 1 /7/ 2010 to 1/3/2011.

Human Skin Samples Preparation

In this in vitro study, human skin, harvested from the surgically excised paniculus (Figure 1) of a 45 years old woman who have undergone an Abdominoplasty procedure at Al-Kadhimiyah teaching Hospital, was used after taking patient's permission. The freshly excised paniculus has undergone a meticulous washing with normal saline then just a layer of 2-3 cm subcutaneous fat was left under the skin. The skin samples were then kept in covered plastic containers in a refrigerator at 4 degree Celsius. Just prior to laser welding experiments, the skin samples were allowed to warm up again slowly to room temperature.

Figure 1 shows a photo plate of part of the excised paniculus composed of human skin and subcutaneous fat.

Fig. (1): A photo plate of the excised human Skin and subcutaneous fat.

The Laser Devices Used

The technical specifications of the chosen 980 nm diode laser device are shown in Table 1. The output laser of this device was delivered to the target site via a 600 micrometer optical fiber. The tip of this optical fiber was kept about 2 mm above the target site during all applications and the spot size of the laser beam has been fixed at 4 mm in diameter. Variable Laser settings and parameters of this laser device were used in this work.

Table (1): VELAS 60, 980 nm diode laser specifications

Laser Type	**GaAlAs Diode Laser**
Model	VeLas60A/B
Wavelength	980nm
Maximum Power	60W
Operation Mode	CW, Single Or Repeat Pulse
Pulse Duration	20-5000ms
Repetition Rate	0.5-20 Hz
Transmission System	600um With SMA905 Connector

Methods

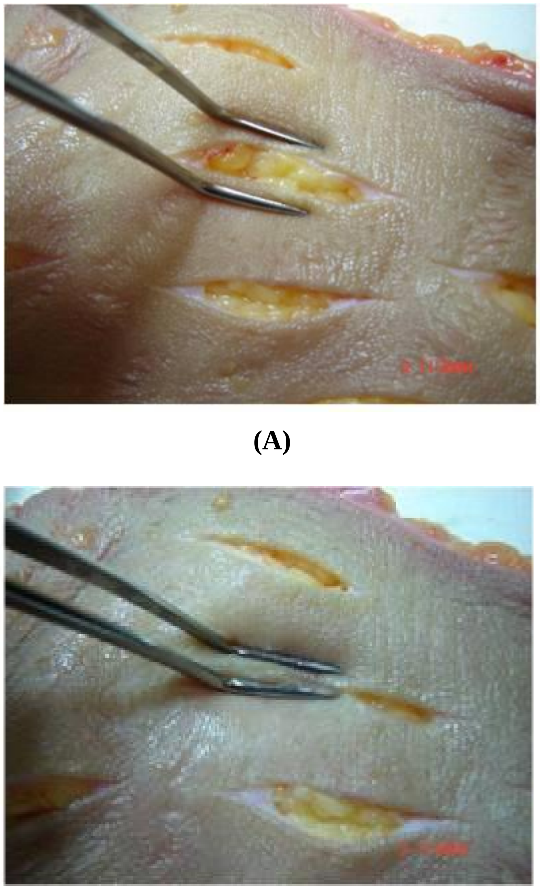
Multiple 0.5-1 cm deep 3-4 cm long full thickness skin incisions were made in the human skin sample, exposing the underlying subcutaneous fat layer (Figure 2).

(A)

(B)

Fig. (2): Multiple 3-4 cm long full thickness skin incisions (B) made in human skin sample (A).

The skin incision edges then were temporarily approximated using dental tweezers (Figure 3) while a 4 mm spot diameter laser was irradiating the incision:



(A)

(B)

Fig. (3): Approximation of the skin incision edges prior to laser irradiation using the dental tweezers

Continuous (at 4mm/sec. speed back and forth laser beam scanning movement), single pulsed spot/spot and repetitive pulse mode laser with scanning movement at variable laser parameters have been applied to the target tissues. The end point of welding of the skin wound was confirmed by naked eye appearance only as swelling and puckering of the wound edges and the wound edge fusion .(Figure 4).After letting the skin incision to cool down back to normal ambient temperature again as confirmed by the non contact infrared thermometer, a gentle force (Figure 5) was applied to the wound edges trying to separate them, noticing whether the welding was of a clinically significant strength or not, in other words, is this weld strong enough to withstand the expected normal movements of a live patient in future studies or not.

Fig. (4): A successfully laser welded skin incision with swelling of the wound edges following laser irradiation.

Fig. (5): Application of gentle force trying to separate the laser irradiated wound edges.

Any successful laser welding experiment was repeated 3 times at same laser parameters setting to confirm the reproducibility of the result.

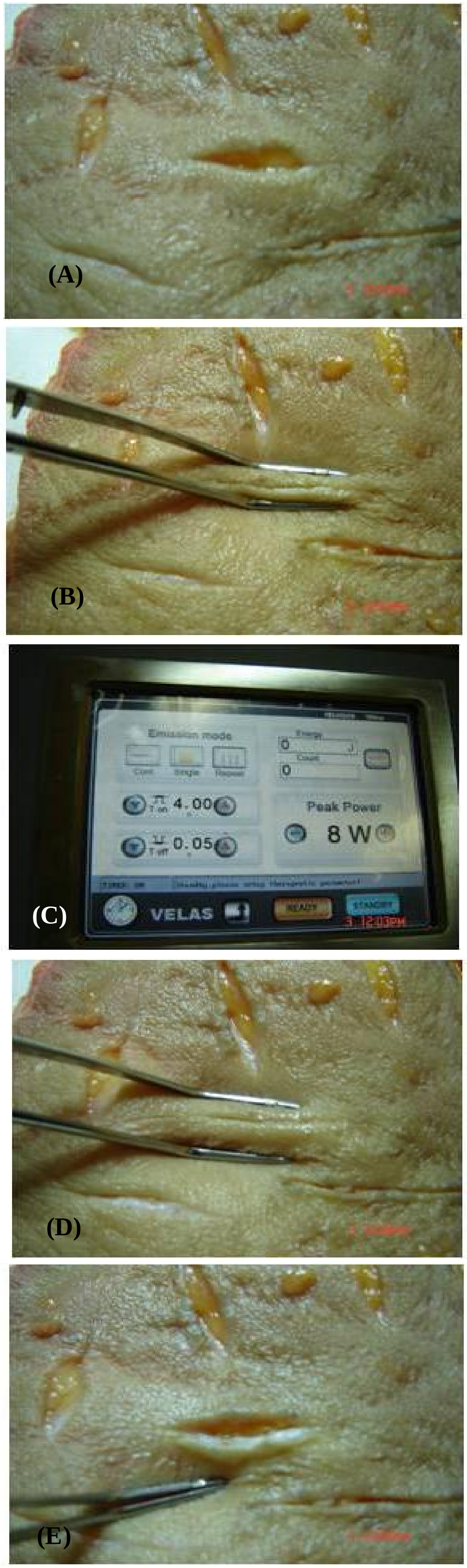
Results

A successful, though weak, skin incision welding has been obtained using the laser parameters and modes of action in table 2 as indicated by wound edge swelling and fusion to the other wound side resisting the natural forces of primary skin contraction that tend to widely separate the wound edges apart .The welding was successful only by use of Continuous or Single pulse, spot by spot welding techniques but no human skin wound welding ever have happened by 980 nm diode laser acting in repetitive pulse mode despite peak powers up to 20 watt was adopted with pulse duration from 0.05 sec. up to 5 seconds at pulse repetition time of 50 msec. giving a maximum repetition rate that the device can deliver. i.e. 20 pulse per second and utilizing a wound scanning laser beam movement speed at 4 mm / second.

Ironically ,although the laser welded skin incisions was successfully closed by laser , the wound closure was of very low tensile strength so that those laser welded wounds could be reopened easily upon even a slight traction force applied to one side of those welded wounds (Figure 6, 7,8) ,in other words, the welding was of no clinical significance since it would not be able at all to withstand normal daily activity movement of the live patient .In fact, this weakness didn't allow even an intact biopsy excision of the welded wound in order to examine the weld by electron microscope study to confirm that it did actually happen.

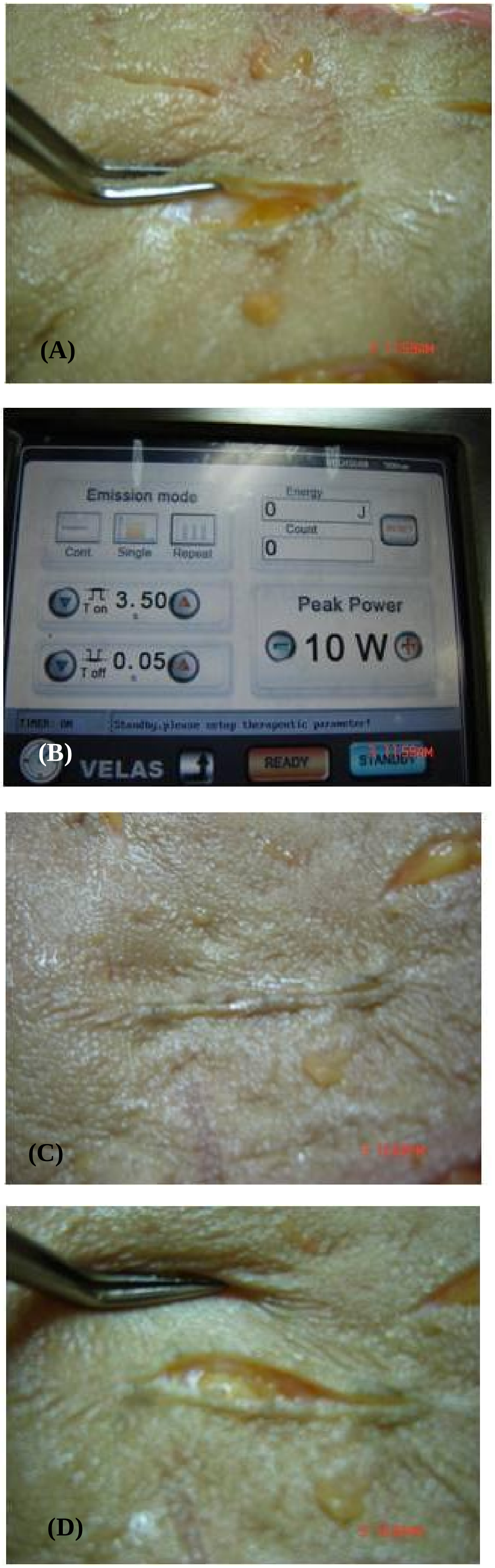
Table (2): 980 nm laser parameters of a successful Skin wound welding

Fluence , Power density	Pulse duration/Sec.	Laser Exposure time/Sec.	Laser mode	Power /watt
0.96 watt/cm^2	--------	360	CW at 4 mm/ scan	1
15.9 watt/ cm^2	---------	240	same	2
39.8 watt/ cm^2	……….	120	same	5
63.7 watt / cm^2	………..	60	same	8
79.6 watt / cm ^{2}	………..	30	same	10
103.5 watt / cm^2	………..	10	same	13
199 Joule / cm^2	5	…………	Single pulse per spot	5
254.7 joule/cm^2	4	…………	same	8
278.6 joule/cm^2	3.5	…………	same	10
254.7 joule/cm^2	2	………..	same	16
159.2 joule/cm^2	1	………..	same	20



Energy 0 J
Count 0
T on 4.00
T off 0.05
Peak Power 8 W

Fig. (6): Skin wound edge swelling indicating coagulation of the collagen and a successful though weak wound welding.



Energy 0 J
Count 0
T on 3.50
T off 0.05
Peak Power 10 W
Standby,please setup therapeutic parameter!

Fig. (7): Despite a successful wound welding, it was of low tensile strength.

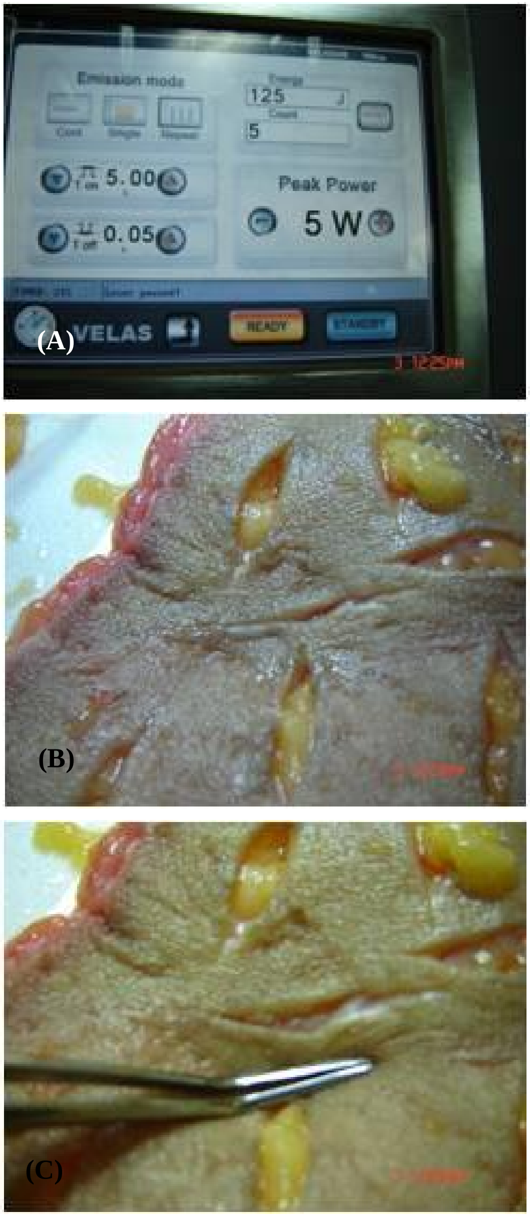


Fig. (8): A successful wound welding yet it could easily be separated by slight traction force applied on one wound side.

Although the utilization of even higher power setting or longer exposure times may results into a stronger welding but this may increases the risk of undesirable thermal wound edge damage too in the absence of real time temperature control feedback systems. In conclusion, they mean that there isn't any particularly unique ideal laser parameter for human skin wound welding but in fact several successful combinations.

The aim should always be to choose the most effective parameter that will yield a successful strong full thickness transmural wound closure yet it prevent any collateral thermal damage to the wound edges. This can be achieved only by simultaneous real time temperature measurement and /or computerized feedback control systems that will automatically change the laser device power irradiating the target wound.

Discussion

In this study, human skin wound welding was tested with a 980-nm laser system, for the first time. The laser light is converted in the tissue into heat, and this heating is what is believed to cause the structural changes in skin dermal collagen leading to welding.

The justification for carrying out this study on *ex vivo* skin samples rather than on a live human being is to avoid plasma oozing from the skin wound edges that may fill the wound gap and disguise the laser welding process by transferring it into a blood soldering process assisted by laser instead of an actual welding process .Actually that might have happened with many researchers who claimed a strong skin welding by laser in their live animal models despite that they mostly didn't undertake any measures to decrease blood ooze in the wound region in their *in vivo* studies (Murat 2006, Simhon 2007, Zajac 2008).

However, by choosing in vitro human skin specimens for this study, the cooling and hydrating effects of the continuous blood flow normally present in the live human skin have also been lost and therefore, the laser parameters applied in this study may not be directly applicable to be used in a live human skin incision closure in future in vivo studies. The skin sample used in this study was obtained from one patient only to minimize the effects of individual variations in human skin optical and thermal properties that may influence the photo thermal effects of laser on the skin and hence induce bias in results of this study since In Iraqi population, there are more than 4 Fitzpatrick types of human skin, each of which have its own optical and thermal skin tissue properties. Additionally, human skin thickness and properties vary also with variation of the body region even in the same individual (Charles 2007). Ideally, those in vitro skin samples used in this study should have even been slowly heated up to 32-37 C^{o} to mimic the normal living human skin surface temperature since this will affect the total amount of laser energy needed to raise up the skin sample tissue temperature for welding or soldering to take place but unfortunately, this was technically difficult since adoption of either a dry heating method (e.g., a warm air blower) or a wet heating method (e.g. a water bath) would change the hydration status of the skin itself and hence its optical properties.

Unlike in most other studies (Abergel 1986, Wider1991, A Murat 2006 , Bassam 2009) dental tweezers, rather than sutures were used to temporarily approximate the created skin wound edges while being lasered . This was to avoid adding an extra operative time and to avoid suture trauma or difficulty of placement. Moreover any placed suture material might burn when laser pass over it leading to loss of the suture tensile strength and wound gapping again prior to successful laser welding /soldering has taken place. The curvature of the end of the dental tweezers was found to be even more beneficial than the straight end of surgical tweezers by avoiding the laser path while holding the wound edges together. Other researchers indeed have even started to use specially designed clamps for this purpose (Simhon 2006).

Laser tissue welding is a difficult process. As the process is not well understood, it is difficult to set laser parameters needed for optimum weld strength and to determine when the weld has been achieved. Energy levels and exposure times that may work well with certain tissues may not be the best for other tissues or situations. Hence , it's quite difficult to compare the results achieved by various researchers with this one especially human rather than animal skin samples were used here for the first time.

Moreover, other researchers, have used different wavelength lasers such as 1064 nm or 1320 nm ,1470 nm or 1980 nm claiming that these may even penetrate deeper in the skin (Capon 2001, Özgür 2006, Temel 2009) . Although many other tissue welding studies have used a more water targeting laser like CO_2 laser (McNally 1999) , most of the laser energy in this case would then be absorbed in the outermost layers of the skin tissue because the absorption coefficient of water at 10600 nm is much higher than that at 980 nm, and thereby ,little of that energy penetrates to the deeper skin layers, thus it may result in a dangerous overheating of the superficial epidermal layer while the deep dermal layer ,the target layer for skin wound welding process, may not heat sufficiently enough to allow the collagen fiber denaturation process to take place, a prerequisite of a successful skin welding process to succeed. Ironically, this relatively poor water absorption of 980 nm laser thus turns to be an advantage by allowing a deeper penetration of this laser into the skin. Additionally, this laser wavelength of 980 nm also has an absorption peak by hemoglobin of blood in future in vivo experiments. This means that even a much higher absorption of laser energy will happen in the vascular dermal layer in the living human skin.

A 4 mm spot size diameter was adopted in this study to ensure an even much deeper penetration of the 980 nm laser into the skin .It is necessary to reduce attenuation of the laser beam caused by light scattering in the subsurface skin layers and, thus, to provide the deepest and most uniform heating of the target site. Moreover, a large spot size also would ensure simultaneous heating of both wound edges to ensure native collagen intertwining necessary for a strong welding process to take place (Coste De 1992 , Nathaniel 2000, Tang 2000, Wolfgang 2002). All other researchers have tried to laser weld wound lengths that are small, like 1-2 cm ,in which the skin primary contraction forces ,due to the skin elastin content ,will not be so strong to gap the wound edges apart .This short wound length was noticed in all researched done in laser assisted wound closure even when the animal model was a huge one like swine , despite the fact that surgical operations ,other than laparoscopic surgeries rarely utilize such short wounds .

That is why, in this study, wounds were made a little longer about 3-4 cm, to ensure that wound edges will separate away enough by primary skin contraction. By doing so, laser skin wound welding has proved to be of low tensile strength and will not be able to withstand the normal daily activity movements in live subjects. Indeed, this seems to be due to small thickness of the collagen containing skin layer, the dermis, in human. This low initial tensile strength of laser welded wounds seems to be an accompaniment of this wound closure method in almost all studies that was done in this regard.

Ironically, in an attempt to overcome this low initial tensile strength of laser welded wounds, some other researchers did place even subcutaneous sutures or even surgical adhesive dressing or tapes over the wound after laser assisted wound closure, to take away any tension on this welded wound hoping to safely bypass the low initial tensile strength period of laser welded wound (Christopher 2001, Yoko 2005).

It's quite inappropriate to compare the laser parameters utilized to achieve human skin incision laser welding in this study with other animal model based studies since human skin differs a lot from animal skin in layer thickness, blood flow and optical properties. There is paucity in literature for studies conducted on real human skin especially using the same laser wavelength. However, what is quite astonishingly noticeable is that the power densities that have successfully welded wounds in live animal skin in those studies are very close to those that this study has concluded for human skin. Again, this may be misleading due to the absence of the cooling and hydrating effect of blood flow in this *in vitro* study compared to others *in vivo* animal studies (Murat 2006).

Theoretically, single pulse per shot ,spot by spot welding using even much longer pulse durations with lower peak powers may result into a stronger wound closure ,however , this would be a difficult approach in this study in absence of real time temperature measurement and /or control system since the wound edge skin layers may then be excessively heated ,and hence get thermally damaged . The thermal relaxation time of the skin should always be respected to avoid any delay or interference with the post welding wound healing process that would take place.

The most sticking result that this study have revealed is the inability to weld any wound by laser acting in the repetitive pulse mode at the tested laser parameters. Obviously, the repetitive pulsed laser photo thermal effect was indeed very localized to the target site and that there was no enough time for heat diffusion from this target site to the surrounding wound margin tissue to take place that would normally allow the intermingling of the deep dermal layer heat denaturized semi liquid collagen fibers (that actually become a gelatin) with the heated albumin of the solder that upon cooling down again would form a single one strong solid cement like substance that strongly bond the wound edges together. Ironically, the undesirable heat diffusion away from the laser intended target site which is responsible for all undesired collateral thermal damage in most clinical laser applications become a necessity in laser assisted wound closure process. The way of skin heating obtained by this laser acting in repetitive mode is not synonymous with continuous mode action even when maximum pulse duration an repetition rate was used .

Review of literature showed a paucity of published researches using this mode of laser action in laser assisted tissue welding /soldering Temel Bilic et al in 2009 study claimed rat wound welding using a continuous and repetitive pulsed mode laser irradiation at 200 ms on 200 ms off pulses, each mode for 5 second exposure from a 1980 nm Thulium laser.

The results also showed weaker wound closure though less tissue damage signs in repetitive pulsed mode than in continuous mode even at same power setting ,That study also revealed that wound welding using this 1980 nm laser can be achieved at very low power of 100 mW only 34.6 W/cm^2 (Temel 2009).

To sum up , in order to achieve a strong wound welding then laser acting in continuous mode at some ideal parameters would guarantee this to happen but ironically, at same time, it may cause thermal damage and delays wound healing process in absence of a suitable real time thermal measurement feedback laser power output control systems. A low powered setting with long exposure time is thus recommended. The majority of previous skin welding studies have used either continuous-wave (CW) delivery of radiation or temperature-controlled welding systems with constant surface temperature feedback. Use of laser in pulsed mode in spot by spot welding ,on the other hand ,though would be much safer and friendly for the wound margins but would not result in a wound closure neither as strong as nor as water tightly sealed as that obtained by continuous mode lasers. Even in this approach ,a relatively long pulse durations are required and thus it appears as if laser is acting in an interrupted continuous mode heating fashion rather than a homogenous heating of the entire dermal skin layer or the solder as when it takes place in an actual continuous mode laser irradiation.

Fried et al. actually also have concluded that continuous laser irradiation actually yields stronger wound closure than spot by spot laser irradiation method .They have applied a strong absorber (India ink) to the apposing edges of the incision and scanned the laser beam rapidly across the weld (Nathaniel 2000). The scanned CW laser welding system thus has provided several advantages over a spot welding technique, including a smoothing out of in homogeneities in the laser beam profile and a more uniform delivery of radiation along the weld site.

Human skin incision welding didn't happen using the same laser parameters that claimed to be successful for welding the rat wounds in Murat et al study, i.e., 6 W peak power and 0.4 sec. pulse duration per shot utilizing the spot welding technique (A Murat 2006). In addition to the differences between human skin and rat skin in structure and optical properties, A Murat et al experiment was done in vivo in which there was a continuous blood supply cooling the area.

Eventually, the blood may have filled the wound gap and lead to laser assisted blood coagulation thereby joining the wound edges together, rather than an actual laser skin welding process as our rat skin welding experiment did show. His main aim was to study the healing pattern in laser welded wounds.

In fact, most studies that have been carried out on live animals aim to study either the healing pattern or the tensile strength of the laser welded/soldered wound. A quick review of them revealed an initial delay phase that happens in the first few days following the laser wound welding in comparison to standard suture closed wounds indicating that there was always some laser induced thermal damage or at least inflammation of the skin margins that delays the start of the wound healing process .

This then have lead to a temporary decrease in the wound tensile strength in first few days following the laser action on the wound .Several researchers have claimed that this delay has been avoided when real time temperature measurement control systems were adopted in laser assisted wound closure (Brosh 2004, Christopher 2001, Lauto 2001,Nathaniel 2000,Simhon 2004).

The most striking advantage of laser assisted wound closure that this study has confirmed so far is that it could really be 4 times faster than conventional technique of skin wound closure ,just like other researchers has found (Christopher 2001).

Conclusion

A 980-nm diode laser wound welding proved to be of low tensile strength to be useful in clinical practice though it can really dramatically shorten the operative time required to close a wound if proper laser parameters were used among an endless effective combinations of laser parameters.

References

A. Murat Gulsoy . Zeynep Dereli . Hasim O. Tabakoglu. (2006): *Closure of skin incisions by 980-nm diode laser welding*. Lasers Med Sci 21: 5–10

A. Zajac et al., (2008): *Real-time control procedures for laser welding of biological tissues.* Bulletin of the polish academy of sciences technical sciences Vol. 56, No. 2,

Abergel RP, Lyons RF, White RA, Lask G, Matsuoka LY, Dwyer RM, Uitto J. (1986): *Skin closure by Nd:YAG laser welding. J Am Ac Dermatol* 14(5): 810-814

Andre M. Gobin. (2005) *Near Infrared Laser-Tissue Welding Using Nanoshells as an Exogenous Absorber.* Lasers in Surgery and Medicine 9999:1–7

B. H. Al-Jarrah. (2009): *Tissue Welding using Diode 800+_10 nm and ND: Yag 1064nm lasers* . A thesis submitted to the laser Instutute for postgraduate studies, Baghdad Univrersity

Bass LS, Libutti SK, Oz MC, et al., (1994): *Canine choledochotomy closure with diode laser-activated fibrinogen solder.* Surgery. 115:398-401.

Bass LS, Moazami N, Pocsidio J, Oz MC, Lo Gerfo P, Treat MR. (1992): *Changes in type I collagen following laser welding.* Lasers Surg Med. 12:500-505.

Bass LS, Treat MR. (1995) *Laser Tissue Welding: A comprehensive review of current and future clinical applications.* Lasers Surg Med. 17:315-349

Bleustein CB, Felsen D, Poppas DP (2000): *Welding characteristics of different albumin species with and without fatty acids.* Lasers Surg. Med 27:82–86

Bleustein CB, Walker CN, Felsen D, Poppas DP. (2000): *Semi-solid albumin solder improved mechanical properties for laser tissue welding.* Lasers Surg Med. 27:140-146.

Brosh T, Simhon D, Halpern M, Ravid A, Vasilyev T, Kariv N, Katzir A, Nevo Z (2004): *Closure of skin incisions in rabbits by laser soldering: II: tensile strength.* Lasers Surg Med 35:12–17

Capon A, Souil E, Gauthier B, Sumian C, Bachelet M, Buys B, Polla BS, Mordon S (2001): *Laser assisted skin closure (LASC) by using a 815-nm diode laser system accelerates and improves wound healing.* Lasers Surg Med 28:168–175

Chan BP, Kochevar IE, Redmond RW., (2002): *Enhancement of porcine skin graft adherence using a light-activated process.* mJ Surg Res 108(1):77–84

Charles H. Thorne, (2007): Grab and Smith plastic Surgery ,6th Edition , Lippincott Williams & Wilkins, a Wolters Kluwer business, ,USA

Christopher S. Cooper. (2001): *Optimal Solder and Power Density For Diode Laser Tissue Soldering (LTS).* Lasers in Surgery and Medicine 29:53-61

De Coste SD, Farinelli W, Flotte T, Anderson RR (1992) *Dye enhanced laser welding for skin closure.* Lasers Surg Med 12:25–32

Elaine Naomi La Joie. (1992): *Tissue Welding: Studies of Pulsed Diode Laser Interaction with ICG Stained Porcine Aorta and Elastin-Based Biomaterial.*

Forer B, Vasilyev T, Brosh T, Kariv N, Gil Z, Fliss DM, Katzir A (2005): *Repair of pig dura in vivo using temperature controlled CO2 laser soldering.* Lasers Surg Med 37(4): 286–292

Fried NM, Walsh JT.(2000) *Laser skin welding: in vivo tensile strength and wound healing results.* Lasers Med Surg. 27:55-65.

Haşim Özgür Tabakoğlu and Murat Gülsoy. (2006): .*In vivo comparison of near infrared lasers for skin welding.* Lasers in Medical Science, Volume 21, Number 1, Pages 5-10.

Judy MM, Nosir H, Jackson RW, Matthews L, Utecht RE, Lewis DE, Yuan D. (1993): *Photochemical bonding of skin with 1,8naphthalimide dyes.* SPIE Proc ;3195:21–24.

Kirsch AJ, Chang DT, Kayton ML, Libutti SK, Treat MR, Hensle TW. (1996): *Laser welding with albumin-based solder: experimental full-tubed skin graft urethroplasty.* Lasers Surg Med 18:225±-30.

Kirsch AJ, Duckett JW, Snyder HM, Canning DA, Harshaw DW, Howard P, Macarak EJ, Zderic SA (1997): *Skin flap closure by dermal laser soldering: a wound healing model for suture less hypostasis repair.* Urology 50(2):263–272

Klioze SD, Poppas DP, Rooke CT, Choma TJ, Schlossberg SM. (1994): .*Development and initial application of a real time thermal control system for laser tissue welding.* J. Urol.;152(pt 2):744-748

Lasers Surg Med.;18:335-344.

Lauto A, Dawes JM, Cushway T, Piper JA, Owen ER. (1998): *Laser nerve repair by solid protein band technique, I: identification of optimal laser dose, power, and solder surface area.* Microsurgery.;18:55-59

Lauto A, Foster LJ, Ferris L, Avolio A, Zwaneveld N, Poole- Warren LA. (2004) *Albumin-genipin solder for laser tissue repair.* Lasers Surg Med 35(2):140–145.

Lauto A, Kirman J, Ohebshalom M, Felsen D, Poppas DP. (1999): *Two-layer film as a laser soldering biomaterial.* Lasers Surg Med.;25:250-256.

Lauto A.(1998): *Repair strength dependence on solder protein concentration: a study in laser tissue-welding.* Lasers Surg Med.22:120-125.

Leo C. Fung. (1999*) Effects of Temperature on Tissue Thermal Injury and Wound Strength After Photothermal Wound Closure.* Lasers in Surgery and Medicine 25:285–290 .

Lon R. Horwitz et al: (1999): Augmentation of Wound Healing Using Monochromatic Infrared Energy. Advances in wound care . January/february

Lynette M Brodie. (2003): *Welding of Skin using Nd:YAG Laser with Bipolar Contact Applicators.* A dissertation submitted to University of Southern Queensland Faculty of Engineering and Surveying,

M. Fried et al . (2000): *Laser Skin Welding: In Vivo Tensile Strength and Wound Healing Results.* Lasers in Surgery and Medicine 27:55–65

Massicotte JM, Stewart RB, Poppas DP. (1998): Effects of endogenous absorption in human albumin solder for acute laser wound closure. Lasers Surg Med. 23:18-24.

McNally KM, Sorg BS, Chan EK, Welch AJ, Dawes JM, Owen ER (2000): *Optimal parameters for laser tissue soldering: II. Premixed versus separate dye-solder techniques.* Lasers Surg Med 26:346–356

McNally KM, Sorg BS, Chan EK, Welch AJ, Dawes JM, Owen ER. (1999): *Optimal parameters for laser tissue soldering, I: tensile strength and scanning electron microscopy analysis.* Lasers Surg Med. 24:319-331.

Menovsky T, Beek JF, van Gemert MJC. (1996): *Laser tissue welding of dura mater and peripheral nerves: a scanning electron* *microscopy study.*Lasers Surg Med. 19:152-158.

Mia Talmor,; Clifford B. Bleustein,; Dix P. Poppas. (2001): Laser Tissue Welding A Biotechnological Advance for the Future ; Arch Facial Plast Surg/Vol 3, July-Sep

Murray LW, Su L, Kopchok GE, White RA. (1989): *Cross-linking of extracellular matrixproteins: a preliminary report on a possible mechanism of argon laser welding.* Lasers Surg Med.9:490-496.

Nathaniel M. Fried et al. (1999): *Radiometric Surface Temperature Measurements During Dye-Assisted Laser Skin Closure: In Vitro and In Vivo Results.* Lasers in Surgery and Medicine 25:291–303

Oz MC, Bass LS, Popp HW, et al. (1989) *In vitro comparison of thulium-holmium chromium:YAG and argon ion lasers for welding of biliary tissue.* Lasers Surg Med. 9:248-253.

Oz MC, Johnson JP, Parangi S, Chuck RS, Marboe CC, Bass LS, Nowygrod R, Treat MR. (1990): *Tissue soldering by use of indocyanine green dye-enhanced fibrinogen with the near infrared diode laser.* J Vasc Surg 11:718-725.

P. E. Grubbs Jr., S. Wang, C. Marini, S. Basu, D. M. Rose, and J. N. Cunningham Jr. (1988): *"Enhancement of CO2 laser microvascular anastomoses by fibrin glue"* J. of Surg. Res., vol. 45, pp. 112–119,

Phillips AB, Ginsburg BY, Shin SJ, Soslow R, Ko W, Poppas DP.(1999) *Laser welding for vascular anastomosis using albumin solder: an approach for MID-CAB.* Lasers Surg Med. 24:264-268.

Poppas DP, Massicotte JM, Stewart RB, et al., (1996): *Human albumin solder supplemented with TGF-b1 accelerates healing following laser welded wound closure.* Lasers Surg Med. 19:360-368

Poppas DP, Mininberg DT, Hyacinthe L, Spencer JR, Schlossberg SM., (1993): *Patch graft urethroplasty using dye-enhanced laser tissue welding with a human protein solder: a preclinical canine model.* J Urol.;150:648-650.

Poppas DP, Stewart RB, Massicotte JM, et al. (1996): *Temperature-controlled laser photocoagulation of soft tissue: in vivo evaluation using a tissue welding model.*

Poppas DP, Wright EJ, Guthrie PD, Shlahet LT, Retik AB., (1996): *Human albumin solders for clinical application during laser tissue welding.* Lasers Surg Med 19:2-8.

S. L. Jacques (1993): *Role of tissue optics and pulse duration on tissue effects during high-power laser irradiation.* App. Opt., vol. 32, pp. 2447–2454,.

Saba Y.Tanno (2010): *Laser Liver Repair ,in Vivo Study.* A thesis submitted to the laser Instutute for postgraduate studies, Baghdad Univrersity

Schober R, Ulrich F, Sander T, Durselen H, Hessel S., (1986): *Laser-induced alteration of collagen substructure allows microsurgical tissue welding.* Science. 232:1421-1422.

Simhon D, Brosh T, Halpern M, Ravid A, Vasilyev T, Kariv N, Katzir A, Nevo Z (2004): *Closure of skin incisions in rabbits by laser soldering: I: wound healing pattern.* Lasers Surg Med 35:1–11

Simhon D, Ravid A, Halpern M, Cilesiz I, Brosh T, Kariv N, Leviav A, Katzir A (2001): *Laser soldering of rat skin, using fiberoptic temperature controlled system.* Lasers Surg Med 29:265–273

Simhon D., Halpern M., Brosh T., Vasilyev T., Ravid A., Tennenbaum T., Nevo Z., and Katzir A., (2007): *Immediate tight sealing of skin incisions using an innovative temperature-controlled laser soldering device: In vivo study in porcine skin",* Ann. of Surg. 245, 206

Small W 4th, Heredia NJ, Maitland DJ, Da Silva LB, Matthews DL (1997): *Dye-enhanced protein solders and patches in laser assisted tissue welding.* J Clin Laser Med Surg 15(5):205–208

Steinstraesser et al. (2010): *Laser-Mediated Fixation of Collagen-Based Scaffolds to Dermal Wounds.* Lasers in Surgery and Medicine 42:141–149

Suh DD, Schwartz IP, Canning DA, Snyder HM, Zderic SA, Kirsch AJ, (1998): *Comparison of dermal and epithelial approaches to laser tissue soldering for skin flap closure.* Lasers Surg Med 22(5):268–271.

Tang J J et al (2000): *A comparison of Cunyite and Fosterite NIR tunable laser tissue welding using native collagen fluorescence imaging.* J Clin Laser Med Surg Jun;18(3):117-23.

Tang J, Godlewski G, Rouy S, Delacretaz G. (1997) *Morphologic changes in collagen* *fibers after 830-nm diode laser welding.* Lasers Surg Med. 21:438- 443.

Temel Bilici, Özgür Tabakoğlu, Hamit Kalaycıoğlu. (2009): *Low-Power Skin Welding by Thulium (Tm:YAP) laser at 1980-nm.*IEEE J. of Sel.Top. in Quan. Electronics.

White RA, Kopchok GE, Donayre CE, et al. (1988): *Mechanism of tissue fusion in argon laser-welded vein-artery anastomoses.* Lasers Surg Med. 88:83-89

Wider TM, Libutti SK, Greenwald DP, et al., (1991): *Skin closure with dye-enhanced laser welding and fibrinogen.* Plast Reconstr Surg. 88:1018-1025.

Wolfgang Baumler et al (2002): *The effect of different spot sizes on the efficacy of hair removal using a long pulsed diode laser.* Dermatologic Surgery 28:118-121

Wright EJ, Poppas DP. (1997): *Effect of laser wavelength and protein solder concentration on acute tissue repair using laser welding: initial results in a canine ureter model.* Tech Urol. 3:176-181

Yoko Kamegaya et al., (2005): *Evaluation of Photochemical Tissue Bonding for Closure of Skin Incisions and Excisions.* Lasers in Surgery and Medicine; 37:264–270

لحام جرح جلد الإنسان بمساعدة ليزر أشباه الموصلات 980 نانومتر:دراسة تجريبية خارج الجسم الحي

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الخلاصة

ان لحام الجروح بمساعدة ذو مزايا وفوائد عديدة مقارنة بالطرق التقليدية.أن الغرض من هذه الدراسة خارج الجسم الحي التي أجريت في معهد الليزر للدراسات العليا في جامعة بغداد هو تحديد مدى فاعلية ليزر أشباه الموصلات 980نانومتر في المساعدة في لحام جروح الجلد لدى الإنسان . لقد استخدم في هذه الدراسة عينات من جلد جدار البطن المستأصل من عملية تقويم جدار البطن لمريضة تبلغ 45 سنة من العمر.تم استحداث عدة جروح طولية قطعية بطول 3-4 سم كاملة العمق خلال عينة الجلد هذه ثم تمت محاولة لحامها بتعريضها لليزر بطول موجي 980 نانو متر وقطر البقعة 4 ملم باستخدام طاقات وأنماط عمل مختلفة . لقد حصل لحام لجروح الجلد ولكنه ذو قوة ضعيفة عند استخدام الليزر عند طاقات وأنماط عمل مختلفة. لقد أظهرت النتائج انه رغم نجاح حصول لحام هذه الجروح باستخدام طاقات وأنماط إشعاع ليزر مختلفة إلا إن هذا اللحام لم يكن بقوة كافية ليكون ذا فائدة سريرية للمرضى.