

The Depth of Thermal Necrosis After SureTouchTM (SoftScanTM) CO₂ Laser Scanner

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ABSTRACT:

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BACKGROUND: SureTouchTM (SoftScanTM) CO₂ laser scanner has recently been introduced for laser skin resurfacing. It is optomechanical flashscanner that can be used in conjunction with a lower power CO₂ laser in the continuous mode. The scanner achieves high power by focusing the CO₂ laser beam to a small spot size of

200 μm , and rapidly scans the focused beam over a variety of scan pattern. The scan size can be variable up to 20 mm. The dwelling time can be adjustable from 396 to 1000 μsec . There were no previous studies for human tissue effect of this scanner.

OBJECTIVES: To define the optimum laser parameters for maximum aesthetic effect of the scanner and to determine the depth of ablation and the depth of residual thermal injury produced with one to three passes of the optimum laser parameters.

METHODS: Normal skin from both ends of fusiform excision at perioral area for a total of 12 specimens were treated with one pass of the following three different power setting. Square- pattern, 2x2 mm. scan area was set with three different power settings of 11, 15, 20 watts, continuous wave CO_2 laser mode. Four different dwelling times, 396, 485, 591 and 698 μsec were used for each power setting. The distal end of postauricular donor skin from another patient requiring full thickness skin grafts following Mohs micrographic surgery for a total of 6 specimens were treated with one to three passes of 11 watts and 2 dwelling times, 396 and 485 μsec . Histologic studies were evaluated by light microscopy and micrometer.

RESULTS: The depth of thermal necrosis after one pass of SureTouchTM CO_2 laser scanner are between 5 and 100 μm . The constant ablation depth after one pass of all parameters measured about 20-50 μm . Increasing the dwelling time and power setting resulted in a corresponding increase in the depth of thermal necrosis. The depth of ablation and residual thermal injury after treated with one to three passes of 11 watts and 2 dwelling time, 396 and 485 μsec are about 20-50 μm and 25-150 μm , respectively.

CONCLUSION: Every parameters in this study can be used for skin resurfacing. The recommended optimum parameters are the power setting of 11 watts and dwelling time of less than 485 μsec because they produced the least residual thermal necrosis. The recommended optimum parameters for maximum aesthetic effect can be use only one pass because the subsequent passes produced the constant ablation depth but increasing the depth of residual thermal necrosis and increasing the risk of scarring.

Key word : Thermal necrosis, SureTouch , SoftScan , flashscanner, laser skin resurfacing

บทคัดย่อ:

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ในปัจจุบันมีการแนะนำการทำรีเซอเฟสซึ่งผิวหนังด้วยเลเซอร์โดยใช้ SureTouch™ (SoftScan™) ซึ่งเป็น Optomechanical แฟลชสแกนเนอร์ ที่ใช้ร่วมกับคาร์บอนไดออกไซด์เลเซอร์กำลังต่ำใน continuous mode สแกนเนอร์นี้ได้รับกำลังสูงจากลำแสงคาร์บอนไดออกไซด์เลเซอร์ที่จุดโฟกัส ขนาดเล็ก 200 ไมครอนและสแกนอย่างรวดเร็วเป็นลำแสงโฟกัสหลายรูปแบบสแกน ขนาดสแกนทำได้ขนาดต่างๆ จนถึง 20 มิลลิเมตร สามารถปรับ dwelling time จาก 396 ถึง 1000 μ sec ยังไม่มีการศึกษาผลของสแกนเนอร์นี้ต่อเนื้อเยื้อมนุษย์มาก่อน

วัตถุประสงค์: เพื่อหาค่าปัจจัยกำหนดที่ดีที่สุดของเลเซอร์สำหรับผลด้านความสวยงาม และ หาความลึกของ ablation และความลึกของการทำอันตรายต่อผิวหนังที่เหลือจากความร้อน โดยดูจากใช้ค่าปัจจัยกำหนดที่ดีที่สุดของเลเซอร์ กระทำต่อผิวหนังที่เดียวกัน 1 ถึง 3 ครั้ง

วิธีการศึกษา: ใช้ผิวหนังปกติจากปลาย 2 ข้างของการตัดเนื้อรูปกระสวยจากบริเวณรอบปาก 12 ชิ้น สแกนด้วยเลเซอร์ 1 ครั้ง ขนาดพื้นที่ 2 x 2 มิลลิเมตร ด้วยกำลัง 11, 15 และ 20 วัตต์ ใน continuous mode ปรับค่า dwelling time 396, 485, 591 และ 698 μ sec ต่อกำลังระดับต่างๆ ใช้ผิวหนังส่วนปลายบริเวณหลังหูของผู้บริจาคผิวหนังจากผู้ป่วยที่ต้องการประณีตผิวหน้า ในการผ่าตัด Mohs 6 ชิ้น สแกนด้วยเลเซอร์ 1 ถึง 3 ครั้ง ด้วยกำลัง 11 วัตต์ และปรับค่า dwelling time 396 และ 485 μ sec และศึกษาผลเนื้อเยื่อด้วยกล้อง light microscopy และ micrometer

ผลการศึกษา: ความลึกของผิวหนังตายจากความร้อนหลังการใช้ SureTouch™ คาร์บอนไดออกไซด์เลเซอร์สแกนเนอร์ 1 ครั้ง อยู่ระหว่าง 5 ถึง 100 ไมครอน ความลึกของ ablation หลังการใช้ 1 ครั้งของทุกๆค่าปัจจัยกำหนดวัดได้ค่าคงที่ประมาณ 20 ถึง 50 ไมครอน การเพิ่มค่ากำลังของเลเซอร์ และ dwelling time จะยังเพิ่มความลึกของผิวหนังตายจากความร้อน ความลึกของ ablation และ ความลึกของการทำอันตรายต่อผิวหนังที่เหลือจาก

ความร้อน เมื่อใช้กำลัง 11 วัตต์ dwelling time 396 และ 485 μsec กระทำต่อผิวหนัง 1 ถึง 3 ครั้ง มีค่าประมาณ 20 ถึง 50 ไมครอน และ 25 ถึง 150 ไมครอน ตามลำดับ

สรุปผลการศึกษา: ทุกๆค่าปัจจัยกำหนดที่ใช้ในการศึกษาครั้งนี้สามารถใช้ในการทำรีเซอเฟสซึ่งผิวหนังค่าปัจจัยกำหนดที่ดีที่สุดที่แนะนำ คือ กำลัง 11 วัตต์ และ dwelling time น้อยกว่า 485 μsec เพราะมันทำให้ผิวหนังที่เสียหายจากความร้อนน้อยที่สุด ค่าปัจจัยกำหนดที่ดีที่สุดเพื่อความสวยงามสูงสุดนี้สามารถใช้เพียงครั้งเท่านั้น เพราะการทำครั้งต่อไปทำให้เกิดความลึกของ ablation คงที่แต่เพิ่มความลึกของผิวหนังที่เสียหายจากความร้อน และเพิ่มความเสี่ยงต่อการเกิดรอยแผลเป็น

คำสำคัญ: ผิวหนังตายจากความร้อน, ช้ำพุขี้, ซอฟต์สแกน, แฟลชสแกนเนอร์, รีเซอเฟสซึ่งผิวหนังด้วยเลเซอร์

The currently available lasers intended for resurfacing incorporate advancement base on Anderson and Parrish's theory of selective photothermolysis.^{1,2} The 10,600-nm wavelength of the CO₂ laser is preferentially absorbed by water, having an extinction coefficient of about 30 μm .^{2,3} The thermal relaxation time of this layer of tissue has been calculated to be less than 1 ms.⁴ If the laser-tissue interaction time is confined to this time period or less by rapid pulsing of the laser or by rapid scanning of continuous beam, then a layer of residual thermal necrosis measuring only 50 to 100 μm because of confinement of thermal diffusion.^{3,5}

The recent well know technology for skin resurfacing is SilkTouchTM flashscanner but the newer advance one is the SoftScanTM (Sahar technologies, Inc.)⁶ SoftScanTM was renamed to SureTouchTM CO₂ laser scanner. (Sharplan Laser,

Inc.). SureTouchTM CO₂ laser scanner^{6,7} is used in conjunction with a lower power CO₂ laser in the continuous mode. The scanner achieves high powers by focusing the CO₂ laser beam to a small spot size of 200 μm and rapidly scans the focused beam over a predetermined scan pattern. A variety of scan patterns is provided in continuous wave mode; square, hexagon, line, parallelogram, rectangle, triangle, and wedge. The scan size can be variable up to 20 mm. for each pattern. The short exposure time (dwelling time) in continuous mode can be adjustable from 396 to 1000 μsec . The full SureTouchTM CO₂ laser scanner device specification is showed in Table 1.^{6,7} there were no previous studies for human tissue effect of this scanner system.

Table 1

SureTouch™ CO₂ laser scanner device specifications

Laser Compatibility	Most Sharplan CO ₂ Lasers
Computerized Scan Modes	Continuous (CW)
Scan Patterns	Square, Hexagon, Line, Parallelogram, Rectangle, Triangle, Wedge
Scan size	Variable up to 20 mm
Dwelling Time	CW Mode Adjustable from 396-1000 microsecond
Control Panel	Microprocessor Control, LCD Display
Electrical Power	110-230 VAC, 50/60Hz

Materials and Methods**The Donor Skin**

The first patient having a solitary neurofibroma nodule at perioral area was entered into the study. Normal skin from both ends of fusiform excision of neurofibroma nodule for a total of 12 specimens were used. The second patient required full-thickness skin grafts following Mohs micrographic surgery was entered into the study. The donor skin for a total of 6 specimens were taken from the postauricular region.

Laser

The laser used was the Sharplan Model 20 C (Sharplan Lasers, Inc.) It was the sealed-off, DC excited CO₂ laser which emit light at 10,600 nm. in the infrared part of the spectrum. The Mode structure was TEM₀₀. Power on tissue were set with three different power setting of 11, 15 and 20 watts continuous wave CO₂ laser mode.

The SureTouch™ CO₂ laser scanner (Sharplan

Lasers, Inc.) is an optomechanical flashscanner that can be used with continuous mode CO₂ lasers. This flashscanner used microprocessor-controller mirror deflection to move a highly focused 200- μ m CO₂ laser beam with constant velocity in varying scan pattern : square, hexagon, line, parallelogram, rectangle, triangle or wedge. The scan pattern in this study was square-pattern, 2x2 mm. Four different dwelling times, 396, 485, 591 and 698 μ sec were used for each power setting.

Skin Treatment

Prior to excision of the neurofibroma nodule in the first patient, the normal skin from both end of fusiform excision were treated with one pass using the previous three different power setting, four different dwelling times and 2x2 mm., square-pattern. The "Char-free" skin debris were not removed with wet applicators. Following treatment,

the tissue was excised and placed in formalin for histopathological analysis.



Fig. 1A SureTouch™ CO₂ laser scanner with the power setting of 11 watts and dwelling time 396 μsec produced about 20-30 μm. ablation depth and 5 μm. residual thermal necrosis. The dermal-epidermal junction remained intact in many foci.

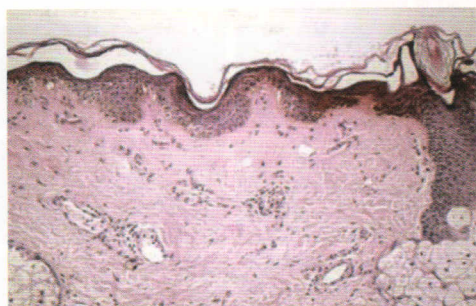


Fig 1B SureTouch™ CO₂ laser scanner with the power setting of 11 watts and dwelling time 396 μsec produced about 20-30 μm. ablation depth and 5 μm. residual thermal necrosis. The dermal-epidermal junction remained intact in many foci.

Prior to excision of the donor skin in the second patient, the distal ends of what was to become the

“dog ears” of the elliptically excised tissue was treated with one to three passes using the power setting of 11 watts and 2 dwelling times; 396 and 485 μsec. Wet application were used to remove the skin debris between subsequent passes of the lasers. Following treatment, the tissue was excised and placed in formalin for histopathological analysis.



Fig 1C SureTouch™ CO₂ laser scanner with the power setting of 11 watts and dwelling time 485 μsec produced about 30-50 μm ablation depth and 25 μm residual thermal necrosis.

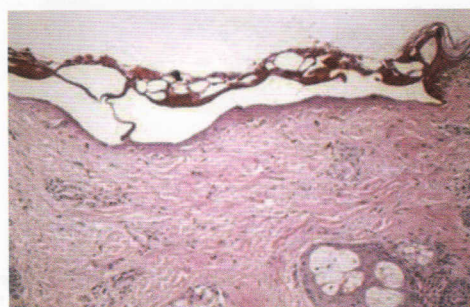


Fig 1D Most parameter of SureTouch™ CO₂ laser scanner completely ablated the epidermis. The depth of ablation are about 30-50 μm. The depth of residual thermal necrosis are between 25 and 100 μm.

The depth of tissue vaporization and thermal necrosis was evaluated by light microscopy and measured for each section of each specimen, using micrometer under low (X100) and high (x400) magnification.

Results

The one pass of SureTouch™ CO₂ laser scanner produced whitening on contact with intact skin as well as visible, square-pattern skin contraction with the application of each parameter in the additional passes. The one pass of all parameters completely ablated the epidermis (Fig.1D) except the power

setting of 11 watts and dwelling time 396 μsec which the dermal-epidermal junction remained intact in many foci. (Fig.1A,B) The depth of ablation from all parameters with the SureTouch™ CO₂ laser scanner measured approximately 30-50 μm. (Fig.1D) except the power setting of 11 watts, dwelling time 396 μsec which the depth of ablation measured about 20-30 μm. (Fig.1A,B) The depth of residual thermal injury after one pass of the SureTouch™ CO₂ laser scanner are between 5 and 100 μm.

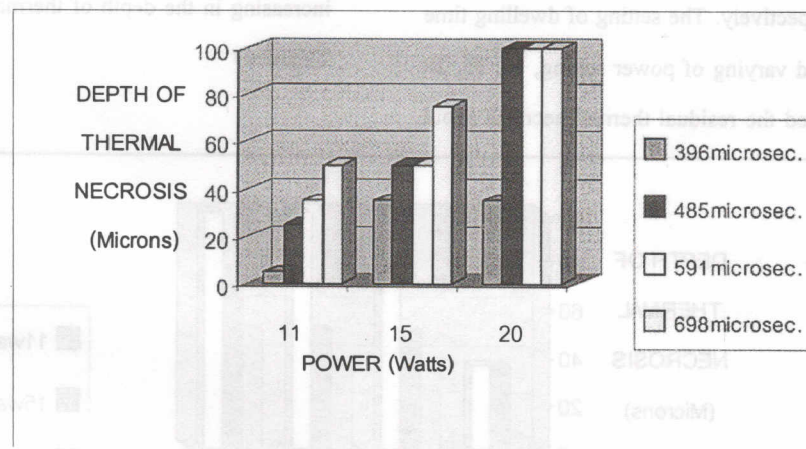


Fig 2 A correlation between the depth of thermal necrosis and dwelling time occurred with each power setting of SureTouch™ CO₂ laser scanner.

At the power setting of 11 watts, four different dwelling time, 396, 485, 591 and 698 μsec, the depth of residual thermal necrosis can be measured about 5, 25, 35, 50 μm, respectively (Fig.1A,C). At the power setting of 15 watts, the same four

different dwelling times, the depth of residual thermal necrosis can be measured about 35, 50, 50, 75 μm, respectively. At the power setting of 20 watts, the same four different dwelling time, the depth of residual thermal necrosis can be measured

about 35, 100, 100, 100 μm , respectively. A correlation between the depth of thermal necrosis and dwelling time occurred with each power setting. Increasing the dwelling time resulted in a corresponding increase in the depth of thermal necrosis. (Fig. 2)

The setting of dwelling time 396 μsec and varying of power setting 11, 15, 20 watts produced the residual thermal necrosis about 5, 35, 35 μm , respectively. The setting of dwelling time 485 μsec and varying of power setting, 11, 15, 20 watts produced the residual thermal necrosis about 25, 50, 100 μm , respectively. The setting of dwelling time 591 μsec and varying of power setting, 11, 15, 20 watts produced the residual thermal necrosis about

35, 50, 100 μm , respectively. The setting of dwelling time 698 μsec and varying of power setting, 11, 15, 20 watts produced the residual thermal necrosis about 50, 75, 100 μm , respectively. A correlation between the depth of thermal necrosis and power setting occurred with each dwelling time. Increasing the power setting resulted in a corresponding increase in the depth of thermal necrosis (Fig.3)

Each power setting, there are correlation between the depth of thermal necrosis and fluence, increasing the fluence resulted in a corresponding increasing in the depth of thermal necrosis (Fig.4 , Table2-4)

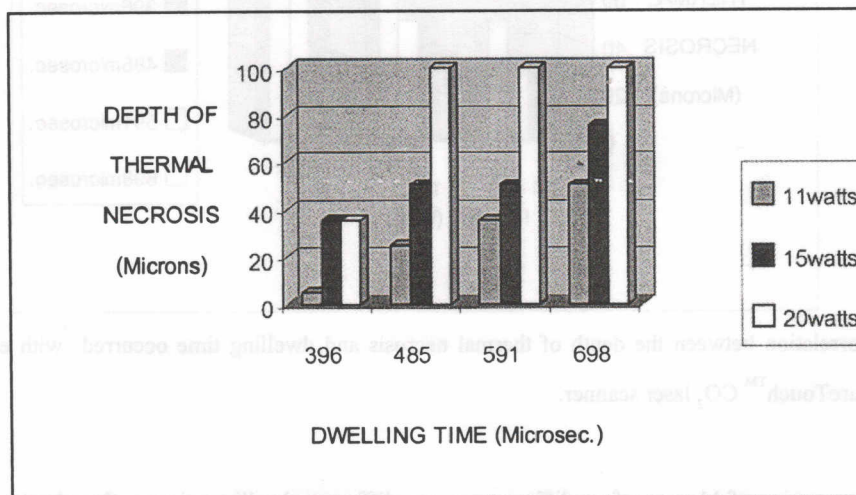


Fig 3 A correlation between the depth of thermal necrosis and three different power settings occurred with each dwelling time of SureTouch™ CO₂ laser scanner

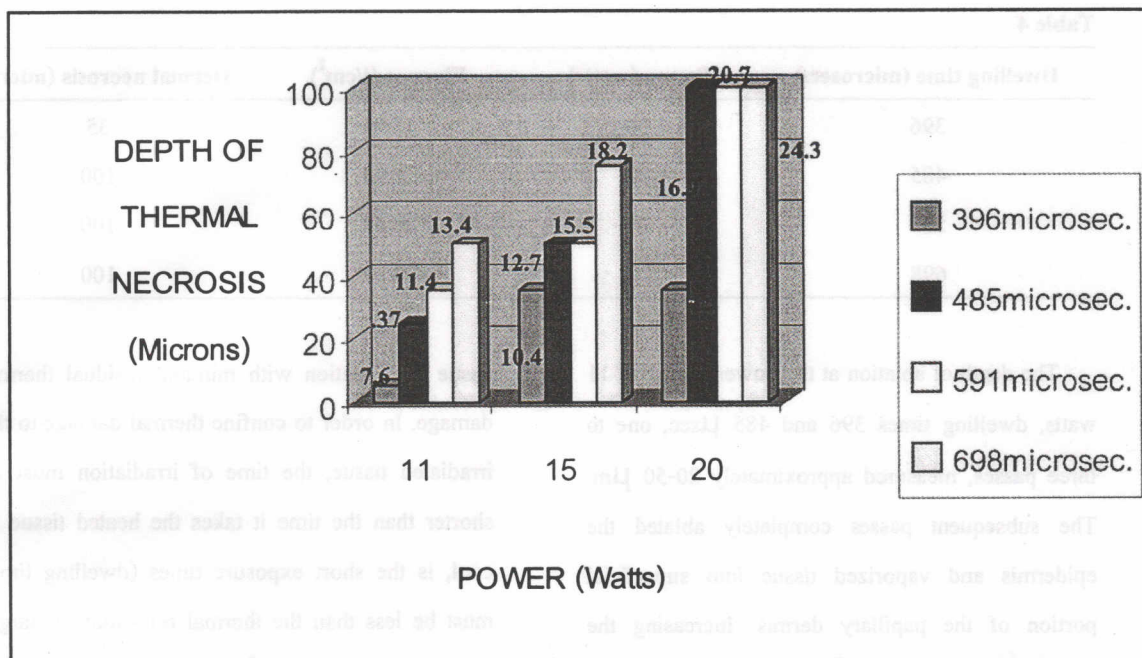


Fig 4 A correlation between the depth of thermal necrosis and fluence, increasing the fluence resulted in a corresponding increase in the depth of thermal necrosis with SureTouch™ CO₂ laser scanner.

Table 2

Dwelling time (microsec.)	Power (watts)	Fluence (J/cm ²)	Dermal necrosis (micron)
396	11	7.61	5
485	11	9.32	25
591	11	11.38	35
698	11	13.38	50

Table 3

Dwelling time (microsec.)	Power (watts)	Fluence (J/cm ²)	Dermal necrosis (micron)
396	15	10.38	35
485	15	12.71	50
591	15	15.51	50
698	15	18.24	75

Table 4

Dwelling time (microsec.)	Power (watts)	Fluence (J/cm ²)	Dermal necrosis (micron)
396	20	13.84	35
485	20	16.95	100
591	20	20.68	100
698	20	24.32	100

The depth of ablation at the power setting of 11 watts, dwelling times 396 and 485 μ sec, one to three passes, measured approximately 20-50 μ m. The subsequent passes completely ablated the epidermis and vaporized tissue into superficial portion of the papillary dermis. Increasing the dwelling time or numbers of passes did not produce increasing the depth of ablation. The first, second and third pass with the power setting of 11 watts and dwelling time 396 μ sec produced the depth of residual thermal injury about 25, 75, and 150 μ m, respectively. (Figure 5) The first, second and third pass with the power setting of 11 watts and dwelling time 485 μ sec produced the depth of residual injury about 50, 100 and 150 μ m, respectively. The depth of residual thermal injury produced increase with subsequent passes for the power setting of 11 watts and dwelling time 396 and 485 μ sec.

Discussion

The Flashscanner technology using in conjunction with a lower power CO₂ laser in the continuous mode have been developed for precise

tissue vaporization with minimal residual thermal damage. In order to confine thermal damage to the irradiated tissue, the time of irradiation must be shorter than the time it takes the heated tissue to cool, is the short exposure times (dwelling time) must be less than the thermal relaxation of target tissue (695-950 μ sec)⁸ Therefore, the dwelling time, 396-698 μ sec of SureTouchTM scanner are in proper range and are less than the thermal relaxation time of skin. For "char-free" tissue ablation, enough energy must be delivered to vaporize rather than coagulate tissue. This vaporization threshold of tissue has been calculated to be approximately 5 J/cm^{2, 4, 5, 9} Above this vaporization threshold, the laser energy is absorbed by the tissue, converted to heat, and rapidly boil the water content of the skin at 100 °C. Such precise vaporization of tissue creates narrow zone of thermal damage, measuring 50-100 μ m.¹⁰ Clinical studies as well as pig skin models suggest that a residual thermally coagulated laser of about 30-150 μ m¹⁰ thickness is ideal for providing enough hemostasis with a minimal risk for scarring. Another factor important to control

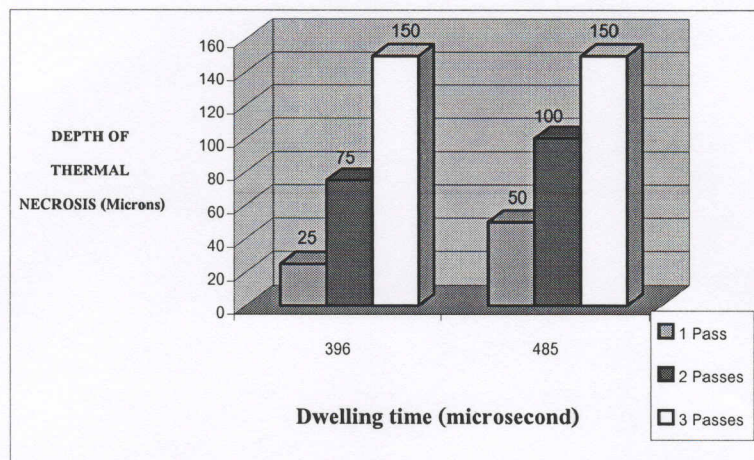


Fig 5 With SureTouch™ CO₂ laser scanner, the power setting of 11 watts and dwelling time 396 and 485 μ sec, the depth of residual thermal necrosis increase with subsequent passes.

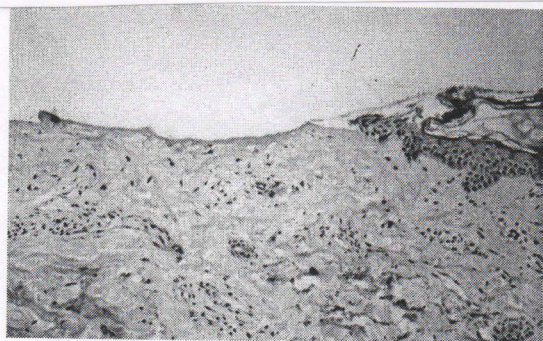


Fig 5A Section taken from skin treated with one pass of 11 watts, dwelling time 396 μ sec.

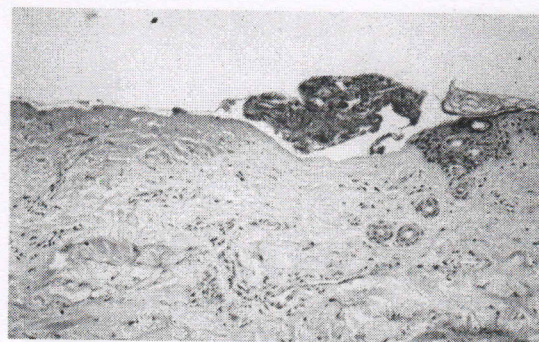


Fig 5B Section taken from skin treated with two pass of 11 watts, dwelling time 396 μ sec.

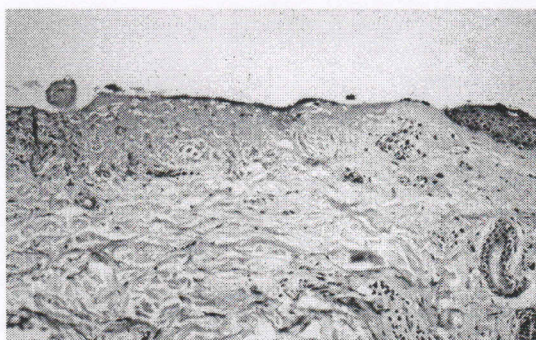


Fig 5C Section taken from skin treated with three pass of 11 watts, dwelling time 396 μ sec.

with CO₂ laser is the depth of ablation produced, as scarring is more likely when vaporization extends into the reticular dermis. All parameter of this study used the fluence between 7.61-24.32 J/cm² which are above the vaporization threshold of tissue. Therefore, all parameters reduced the heat or thermal damage to surrounding the laser impact site. The depth of thermal necrosis after one pass of SureTouchTM CO₂ laser scanner are between 5-100 μ m. The ablation depth after one pass of all parameters measured about 20-50 μ m. Every parameters in this study can be used for laser skin resurfacing but the recommended optimum parameters are the power setting of 11 watts and dwelling time of less than 485 μ sec because they produced the least residual thermal necrosis (5-25 μ m)

One pass after SureTouchTM CO₂ laser scanner with all parameters ablated entirely through the epidermis, except the power setting of 11 watts and dwelling time 396 and 485 μ sec which the dermal-epidermal junction remained intact in many foci. Because the zone of residual thermal damage increased with subsequent passes but constant ablation depth, the recommended optimum parameter for maximum aesthetic effect can be use only one pass for reducing risk of scarring. The increasing of residual thermal damage with subsequent passes may relate to a dehydration effect¹⁰ of the CO₂ laser on the water content of the

skin, with increasing thermal damage resulting from the treatment of partially desiccated tissue. The visible skin contraction produced upon laser contact on the first and subsequent pass may relate to this phenomenon, or alternatively, to shrinkage of collagen fibers. There may be additional beneficial therapeutic effect that relates to heat-induced collagen shrinkage following SureTouchTM CO₂ laser scanner using conjunction with CO₂ laser. The collagen shrinkage may contribute to the apparently persistent skin-tightening effect. An increasing understanding of laser-tissue interaction of SureTouchTM scanner using conjunction with CO₂ laser in many parameters help us producing efficient tissue vaporization with an appropriate amount of residual thermal coagulation and excellent depth control. The SureTouchTM CO₂ lasers scanner device specification showed that it can be use with most Sharplan CO₂ lasers. It required at least 20 watts continuous wave laser which is the least expensive compact CO₂ laser system. The variety of scan pattern in size up to 20 mm. can reduce the operation time. The adjustable dwelling time from 396 to 1000 μ sec can be applied for different skin location and other skin disorders. The further clinical studies of this scanner for skin resurfacing and treating skin disorder will be performed.

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