Subdermal Carbon Dioxide Laser Cutaneous Contraction

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Background: Conventional carbon dioxide (CO₂) skin laser resurfacing reverses the effects of photoaging. A recent clinical series reported the efficacy of performing subdermal CO₂ resurfacing to obtain the same skin contraction as epidermal skin resurfacing.

Objective: To assess surface area contraction that occurs with subdermal CO₂ laser resurfacing in the rat model.

Design: A nonrandomized control study was performed using 32 rats. The 3 test groups were divided by CO₂ laser strength (5 vs 7 W) and the pattern of resurfacing (cross-hatched vs parallel lines).

Materials and Methods: The rats underwent subdermal continuous 2-mm defocused CO₂ beam treatment of the right-sided experimental flap. The left subdermal flap acted as a control. In the first group (n=12), a subdermal cross-hatching of the subdermal flap was performed with 7 W. The second group (n=10) was resurfaced in a parallel fashion with 7 W. The third group (n=10) was resurfaced in a parallel fashion with 5 W. Measurements of skin area were taken immediately after laser resurfacing and 3 weeks after the treatment.

Results: None of the treatment arms showed a change in skin surface area immediately or 3 weeks after treatment. In the first treatment group, all of the treated flaps showed an entire full-thickness slough. Of the controls, 75% showed minimal sloughing. The second and third experimental groups showed a 100% slough of the flaps. Of the 20 control flaps in the second and third groups, only 1 had a partial slough.

Conclusions: In this animal model, subdermal CO₂ laser resurfacing showed a 100% rate of skin sloughing. No change in skin surface area was evident immediately or 3 weeks after treatment.

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Facial rejuvenation by the removal of the epidermis and superficial layers of the dermis has been performed for many years. The resulting reepithelialization, collagen regeneration, and remodeling provide for the desired youthful appearance of the treated skin. Various methods have been used in the past, including mechanical dermabrasion and chemical peels, to achieve similar clinical results. These techniques have inherent technical disadvantages and potential side effects that have limited their widespread application. Mechanical dermabrasion requires extensive experience and technical skill to obtain consistent results. Medical personnel are placed at risk of bloodborne infectious agents during the mechanical dermabrasion procedure. Chemical peels are variable in their depth of penetration and have their own potential risks and side effects that make them less than ideal for general use. In the past few years, technical developments of pulsed and scanning carbon dioxide (CO₂) lasers for skin resurfacing have revolutionized the clinical applications for these lasers. These recent developments have made facial rejuvenation easier to perform. The CO₂ laser allows for predictable depth of penetration and corresponding results. Clinical outcomes are consistent and patient satisfaction is high.

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Aging skin ultrastructure

Aging skin results from both endogenous and exogenous factors. Endogenous changes of aging include dermal atrophy, loss of elastic fibers, loss of inherent elasticity, and a decrease in subdermal adipose tissue. The exogenous factors responsible for skin
MATERIALS AND METHODS

Sprague-Dawley rats were anesthetized using ketamine hydrochloride (1000 mg/mL at a dose of 75 mg/kg intraperitoneally) and xylazine hydrochloride (20 mg/mL at a dose of 5 mg/kg intraperitoneally) in compliance with the Louisiana State University Medical Center Animal Resources protocol. The dorsal flanks were shaved on each rat and a standardized grid was used to tattoo a 3 x 5-cm rectangle on each flank. Next, an incision was made approximately 1.5 cm cephalad to the previously marked grid. Under sterile conditions, a subdermal flap was raised on each flank. The experimental side (right) subdermal flap was laser resurfaced with a continuous 2-mm defocused CO2 beam (MD30 carbon dioxide laser; Laser Engineering Inc, Milford, Mass); the left subdermal flap acted as a control. Both flaps were closed with surgical staples.

The study consisted of 3 treatment groups. In the first group (n=12), a cross-hatching of the subdermal flap was performed with a CO2 laser power setting of 7 W (as described in the original article). The second group (n=10) was resurfaced subdermally in a parallel fashion (perpendicular to the long axis) with a power setting of 7 W. The third group (n=10) was resurfaced subdermally in a parallel fashion (perpendicular to the long axis) with 5 W. The amount of immediate dermal contraction was measured as a change in the area of the 3 x 5-cm square. The animals were then observed for immediate and delayed postoperative changes. The animals were killed 3 weeks after the operation, the tattooed rectangle was then measured, and the area was calculated for changes. Histological examination was performed to assess any changes in the dermal collagen orientation. Clinical photographs were also taken to document the outcomes of the study.

One of the characteristics of the CO2 laser resurfacing is the obvious skin contracture that occurs during the actual procedure and appears to persist in the postoperative period. The resulting decrease in skin redundancy obviates the need for performing more invasive surgical procedures in many patients.9,10

The actual cause for skin shrinkage is not known. The immediate contracture may represent the ablation of water molecules from the epidermis, or thermal coagulation of proteins within the dermis.10-14 The long-term postoperative dermal thickening and contracture may be related to thermal changes, release of growth factors,15 or the modification of the extracellular matrix. Heat-induced collagen contracture was first reported in studies of corneal reshaping about 100 years ago.16 At temperatures of 55°C to 60°C, the type I collagen fibrils shorten by as much as one third their original length.16 Tissue necrosis occurs at temperatures greater than 70°C so that collagen shrinkage can be induced at a predictable temperature range without concern of thermal tissue necrosis damage. Hydrothermal shrinkage of the collagen fibers of rat skin have been well studied.17 The thermal studies performed by Allain et al17 in 1980 showed an initial relaxation prior to “isometric shrinkage,” theoretically due to the breaking of the collagen cross-linking and then their re-formation.

Many recent studies have been performed to assess the resulting skin contracture. It appears that there is a direct effect by the CO2 laser from the thermal energy on the collagen fibers. Some studies report that the individual collagen fibers within the dermis actually shorten once subjected to the CO2 laser. This has been most convincingly shown by electron microscopy studies that reveal the reduction in size of the collagen fibers.18 Sieckel et al19 studied the CO2 laser effects on the skin of guinea pigs. A reduction of 27% in length and 40% in width was seen immediately and persisted 12 weeks postoperatively. Electron microscopy showed a significant shortening of the collagen fibers by 7.45% that persisted the length of the study (12 weeks). Campbell et al20 found a similar decrease in the periodicity of individual fibers in both CO2 laser and mechanical dermabrasion pig skin.
An average decrease in periodicity of 9 nm and 12 nm was found in the dermabrasion and the CO2 laser resurfaced skin, respectively.9

In contrast, Collawn et al10 studied the immediate effects of CO2 laser resurfacing on human preauricular skin. Using electron microscopy, the immediate “contraction” seen with the CO2 laser was due to a loss of extracellular gel matrix. The ablation of this surrounding matrix caused a compaction of the collagen fibers together resulting in the observed “shrinkage” of skin tissue. Collagen fibers were unchanged except at the surface of specimens. No shrinkage of the collagen fibers was observed.

SUBDERMAL CO2 LASER RESURFACING

In an article by Cook,18 a technique is described in which the platysma fascia and undersurface of the dermis of the neck is laser resurfaced to induce contraction of these structures. Approximately 20% of the area of the platysma and subdermal skin is laser treated in a randomized criss-crossing fashion with the UltraPulse 5000 CO2 laser using a 7-W defocused setting. The 100 patients he described had a better clinical outcome than traditional tumescent liposculpture of the submental neck.18 There was minimal scarring without instances of sloughed overlying skin. No quantitative description of the amount of skin contracture was noted from the subdermal laser resurfacing process. This technique has never been reported in the literature. The objective of this study was to assess the degree of skin contracture with this new method.

RESULTS

None of the treatment arms showed an immediate change in skin surface area after subdermal laser resurfacing (immediately after laser resurfacing or 3 weeks after treatment). During the course of the procedure, contracture of the subdermal fascia appeared from the immediate lasering but this did not affect the overlying dermal structures. In addition, and possibly more important, there was almost universal sloughing of the dermis originating from a subdermal eschar (Figure 1). In the first treatment group (n=12), all of the experimental laser-treated flaps showed an entire full-thickness slough. Of the controls, 75% showed minimal sloughing of the dermis. For the experimental side, the initial slough average was 5 days with an average completion rate of 10 days and included the entire flap. The control areas showed an initial slough average of 7 days with an average completion rate of 14 days. In the controls, the area of slough was usually a gravity-dependent portion with obvious accumulation of fluid under the flap. Prior to scarring of the sloughed area, no change in skin surface area was evident at 3 weeks after treatment. The second and third experimental groups showed a 100% slough rate of the tested flaps. The average flap showed approximately 70% loss of the area, which consisted primarily of epidermalysis. Of the 20 control flaps in the second and third groups, only 1 flap had a partial slough of approximately 60%.

Histological evaluation of the experimental and control sites was performed at 3 weeks. Only areas of the experimental sites in which no eschar was clinically evident underwent biopsy and were sent for histological evaluation. The tissues were stained with hematoxylin-eosin. In review of the histological slides, particular attention was made to collagen orientation within the dermis and evidence of tissue damage from the surgical procedure and the CO2 laser. The experimental slides did not show any change in the orientation of collagen fibers within the dermis. No evidence of histological tissue damage from surgery or the laser therapy was evident at 3 weeks when control biopsy specimens (Figure 2) were compared with experimental specimens (Figure 3).

COMMENT

The advantageous effect of dermal contraction with CO2 laser resurfacing develops due to unknown causes. To obtain the dermal contraction, patients must go through a recovery period. Reepithelialization can take approximately 2 weeks and loss of erythema can take up to 6 months for complete healing. The technique of subdermal CO2 laser resurfacing attempts to accomplish the goal of dermal contraction without the inherent recovery period.
In this animal model, subdermal CO₂ laser resurfacing showed a 100% rate of skin sloughing. No change in skin surface area was evident immediately or 3 weeks after treatment. In this study, subdermal laser resurfacing produced unfavorable results in all experimental groups without any beneficial effect. Future studies are warranted to further assess the efficacy of subdermal CO₂ laser resurfacing for dermal contraction.

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REFERENCES


Our animal study failed to support the clinical observations of dermal contraction with subdermal laser resurfacing. None of the treatment arms showed a change in skin surface area after subdermal laser resurfacing, immediately after laser resurfacing, or 3 weeks after treatment. In this animal model, subdermal CO₂ laser resurfacing showed a 100% rate of skin sloughing. The dermis receives its blood supply from the subdermal vascular plexus. Interruption of this subdermal vascular plexus would result in a devascularization of the overlying skin, subsequent sloughing, and scarring. In the biopsy specimen of the nonsloughed rat skin areas, no effect on the dermal collagen was evident at 3 weeks after treatment. Our findings do not support an effect by the subdermal resurfacing to cause dermal contraction.

Possible explanations for our contradictory findings are the inherent differences in the rat model and the type of CO₂ laser used. The thinner dermal structures of the rat may have led to the universal sloughing of the overlying skin. The continuous-wave CO₂ laser, despite alteration of the resurfacing pattern and limiting contact time, may still cause substantial thermal damage as compared with the ultrapulse CO₂ laser system. The decreased power, the defocused beam, and the minimal contact with the tissues should theoretically limit the amount of subdermal thermal exposure. However, it still may not have been enough to achieve the same decreased thermal effect seen with the ultrapulsed laser. In addition, we tried altering the random cross-hatching pattern. Lasering in a parallel fashion to the shorter dimension of the raised flap was performed to allow blood flow from the lateral aspects of the flap; this did not provide any additional benefits.

Future studies will be performed using an ultrapulsed laser such as the UltraPulse 5000 to investigate this mode of laser delivery to the subdermal tissues in the rat model. As additional information is obtained as to the cause of dermal contraction induced by CO₂ laser resurfacing, the subdermal application may actually be a viable alternative.