To Debride or Not to Debride? That Is the Question: Rethinking Char Removal in Ablative CO_2 Laser Skin Resurfacing

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BACKGROUND The treatment standard for laser skin resurfacing (LSR) includes aggressively wiping away the char with moist gauze before and after each pass to prevent heat buildup and lateral tissue damage from existing char. No published study has addressed not debriding between passes with traditional higher fluence, high-density, multipass CO_2 LSR in humans.

PURPOSE The objective was to disprove the dogma that wiping away the laser char between treatment passes is necessary.

MATERIALS AND METHODS A total of 158 patients were treated over a 23-month period with multipass, nondebrided CO_2 laser resurfacing (6 J/cm^2, density 6). A small series of split-face studies were performed by debriding one side and not debriding the other side after each pass, and 89 full-face patients were treated without debriding any char between two or three passes. Histologic and photographic studies were performed in selected patients to determine the differences between debrided and nondebrided techniques.

RESULTS None of the nondebrided patients experienced significant complications. Operative times were shortened as was postlaser pain and erythema.

CONCLUSION Histologic analysis showed that three passes of 6 J/cm^2 with a density of 6 produces extremely similar epidermal and dermal changes regardless of debriding between passes or not. This is the first study in humans using high-energy, high-density, multipass LSR without debriding between passes.

The authors have indicated no significant interest with commercial supporters.

Carbon dioxide lasers have become an important tool in aesthetic surgery. The ultrapulse CO_2 laser's advantage, based on photothermolysis with a high-energy pulse, is the predictable ability to vaporize the upper layer of skin, tighten collagen bundles, and induce a local inflammatory reaction with epithelial proliferation.[1,2]

The 1990s ushered in CO_2 laser technology for facial resurfacing and dramatically changed cosmetic facial surgery by displacing previous options of deep chemical peel and dermabrasion. Like many new procedures, laser skin resurfacing (LSR) over the past decade has gone from new, to overused, to less used, for a multitude of reasons. Since the mainstream introduction of CO_2 LSR, many nonablative and minimally ablative treatments have been introduced.[3–8] These techniques, although less invasive, have largely failed to produce significant, repeatable, and long-lasting results when compared to ablative CO_2 LSR. This has led many surgeons to rethink the usage of CO_2 LSR and search for means to lessen the negative effects of CO_2 resurfacing.[9] It is the author's opinion that CO_2 LSR is regaining popularity and that mitigating the more unpleasant effects (postoperative pain, wound care, extended erythema) will accelerate a more broad acceptance of this modality.

Although the CO_2 laser is still the gold standard for skin resurfacing, it is not without problems. Scarring from overtreatment and delayed hypopigmentation presented problems when a litany of specialists adapted or experimented with this technology.

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ISSN: 1076-0512 • Dermatol Surg 2008;34:1200–1211 • DOI: 10.1111/j.1524-4725.2008.34259.x

Although these problems were frequently conquered with experience, extended postlaser erythema remains a significant drawback for patients and practitioners.[10,11] The postlaser redness is an obvious factor of the induction of a burn, but was also aggravated by mechanical debridement of the laser eschar between passes.[12–14] Debriding between multiple passes was initially suggested to prevent the char from serving as a heat sink as a result of pulse stacking, which could cause increased lateral thermal damage.[12–22] This extended erythema (sometimes lasting months) provided a major drawback for patients considering aggressive laser resurfacing. As a general rule, reepithelialization required a full 2-week period and laser erythema can persist for up to 12 weeks.[13] An additional caveat to reduce postlaser erythema was to disregard previous protocols[23] and abandon the use of prelaser tretinoin.[12,13]

The Literature and Research Road to Not Debriding between Laser Passes

Over the years, multiple practitioners have discussed not debriding between laser passes but feared the problems reported with pulse stacking. Immediate overlapping of laser passes was shown to be harmful in several animal studies[24,25] and in excised human skin.[26]

David and Ruis-Esparza in 1997,[12] in a human study, observed that healing time was considerably shorter when the skin heals after laser injury alone, as opposed to healing from laser injury and from friction due to rubbing with saline gauze. Their studies surmised that potential complications such as scarring, textural changes, prolonged erythema, and inordinate pain can also be diminished by minimizing char debridement since much of the nonspecific mechanical damage to the tissue is eliminated.

This represented a step forward in nondebridement but did not represent a full-face, multiple-pass, high-density, nondebrided technique. The face was also treated with a combination of the 3-mm collimated handpiece and only a partial single pass using the computer pattern generator (CPG) as opposed to multiple CPG passes that were nondebrided. In addition, these authors used lower pattern densities of 1–2 for eyelids, 3–4 for facial skin. Finally, although they did not wipe away the char with wet gauze, they did technically debride the laser wounds. In their description of the procedure concerning the individually treated rhytides, it is noted that “carbonized material is carefully removed after each pass with a cotton-tipped applicator soaked in normal saline or hydrogen peroxide after each pass.” They further state that “this is very important since carbonized material heats up quickly and does lose heat slowly. That can be a source of unwanted thermal damage to the dermis.”

In an additional split-face study (on a single patient), these authors debrided between the first and second pass on one side and treated the other side with a single pass that was not debrided and the char left in place.[13] As expected, postlaser erythema persisted longer on the multipass side and the authors concluded that “the depth of ablation (number of passes) will correlate with the degree and duration of postoperative erythema.” They further added that “repeated rubbing with gauze when removing char has the effect of mechanical dermabrasion and produces added trauma to the tissues and leaving the eschar from the final pass in situ is recommended.”

Lent and David[14] repeated these treatments of using the collimated handpiece for two passes on deep rhytides and then treating the remainder of the face with a single nondebrided pass. Again, like the previous studies, this was not a true, multipass, full-face, CPG treatment with high-density settings.

In 1999, Ross and coworkers[15] performed a study on a pig model that showed that when single-pass laser wounding on pig skin was not wiped (debrided with wet gauze), the level of wounding was decreased (when compared to wiping away the single pass). Significant in this study was the finding that not wiping for multiple-pass laser wounds significantly increased the depth, variability, residual thermal damage, and necrosis resulting in prolonged healing. This would portend that not debriding between multiple-pass, high-fluence LSR in humans would be a detrimental process.

Yuksel and colleagues in 2001[27] performed split studies in rats and concluded that wiping vaporized debris every two passes is the most reliable laser treatment modality. In 2003, Collawn and coworkers[28] performed a nondebridement study on humans. Postlaser skin biopsies were examined using direct immunofluorescence with antibodies to specific epidermal and basement membrane proteins. Biopsy specimens taken immediately after resurfacing showed a greater injury to epidermal and basement membrane proteins when skin was wiped with saline-soaked gauze after laser passes than when there was no debridement after two passes. This study concluded that nondebridement of the skin at the time of resurfacing along with the use of postoperative occlusive dressings led to the rapid reestablishment of a multilayered epidermis only 2 days after resurfacing.[28] This appears to be the first human study with high energy, multiple, nondebrided laser passes that histologically evaluates healing of debrided versus debrided laser treatment. Although this was an excellent and very scholarly study and article, there are significant differences between the article by Collawn and colleagues and this author's current study. The study by Collawn and colleagues was limited to nine patients, only five of whom were treated with full-face laser resurfacing. In addition, only two nondebrided passes were used and, more importantly, the fluence and/or density was lowered on the second pass, and some parts of the face were treated with only a single pass.

Other authors have described a nondebrided technique. A low-energy, single-pass laser technique combined with intensive skin care treatment was described by Chajchir and Benzaquen.[29] Their premise was a more conservative treatment can yield excellent clinical results in treating actinic damaged skin and the single laser pass in not debrided. Although this study describes a nondebrided technique, it is similar to the previously quoted studies in that it does not apply the high-fluence, high-density, multipass, CPG-directed full-face treatment.

Unlike all the previously quoted studies, this author's study involved a larger cohort; 43 full-face patients treated with multiple passes using the CPG with a high-energy (6 J/cm^2) and a high density of 6 (35% overlap; Table 1). Of this group, 33 patients were treated with two nondebrided passes, and 10 patients were treated with three nondebrided passes, which were all the same fluence and density. This study represents more aggressive treatment with consistently higher fluences, densities, passes, and patient treatments as well as utilizes open wound care. Table 1 illustrates the breakdown of the full-face nondebride study patients.

The Clinical Road to Not Debriding between Laser Passes

The original advantage of CO_2 LSR over deep chemical peel and dermabrasion was the ability to precisely ablate exact and predictable levels of tissue. The addition of vigorous mechanical debridement with saline-soaked gauze added further tissue insult, which negates the precision of ultrapulsed laser technology (Figure 1). These observations encouraged further experimentation in the attempt to eliminate debriding the laser char altogether.

In an investigational manner, segmental resurfacing was conducted in 68 patients using high-energy fluences (6 J/cm^2) on the lower eyelids using 2 (and occasionally 3) stacked passes without debriding. Leaving the char between passes did not affect the

TABLE 1. Nondebride Full-Face Study Patients

	Number of passes		
	One	*Two*	*Three*
Female	46	30	5
Male	1	3	5
Total	47	33	10

Figure 1. Not debriding the laser char between passes produces less tissue damage. The debrided skin exhibits greater insult as evidenced by hemorrhage on the patient's left side. The act of debriding negates the precision effects of ultrapulse laser ablation and increases the wounding, pain, and healing.

final outcome or produce increased scarring or hypopigmentation and actually reduced the persistence of postlaser erythema (Figure 2).

The eyelid study gave way to a series of split full-face studies with patient consent. Using moderately high-fluence and high-density settings (Encore Ultrapulse CO_2 laser [Lumenis Inc., Santa Clara, CA], 80 mJ (6 J/cm^2), density 6 (35% overlap), square pattern, size 9), two passes were made with the same settings.

One side of the face was debrided between passes, and the other side of the face was not debrided at all (Figure 3). It is noted that when using two laser passes that the entire face is treated with the first pass before applying the second pass. This was done instead of "double firing" the laser at the same time on the same square and allowed for heat dissipation as opposed to firing two consecutive laser passes immediately at the same spot (pulse stacking).

After carefully following the split-face patients clinically and histologically, it became clear that non-debriding was a safe technique. Not only was there no increase in complications, but leaving the eschar in place served as a postlaser biologic dressing protecting the denuded dermis and decreasing postlaser and faster resolution of postlaser erythema. Intraoperative treatment time was also greatly reduced because not debriding between passes allowed much faster resurfacing. Previous to this nondebridement study, the author utilized postlaser dressings for pain control and wound protection (Silon, Biomed Sciences, Allentown, PA), since leaving the char intact acted as the dressing and only simple petroleum jelly open dressings were employed after adapting the nondebridement technique. Leaving the nondebrided char eliminated not only the Silon membrane and retaining netting but also the related hassles. These dressings were intimidating to the patient and family, quickly became soiled, were uncomfortable, and required increased follow-up appointments to manage. Eliminating the dressings was very welcomed by the surgeon, patients, and staff. It also became much easier to recommend and promote LSR treatment to patients.

After the success with the initial two-pass test subjects, the multipass, high-density, nondebrided laser resurfacing technique was increased to three nondebrided passes in split-face studies. Again, there were no untoward effects of the nondebrided side.

Obviously, a three-pass technique is not necessary for all patients and is primarily reserved for severe actinic damage or acne scarring. Upper eyelids in these patients were only treated with one pass and the lower lids with two passes, but the remainder of the face was treated with three nondebrided passes. In some patients, severe damage was treated with four to five nondebrided passes on selected areas

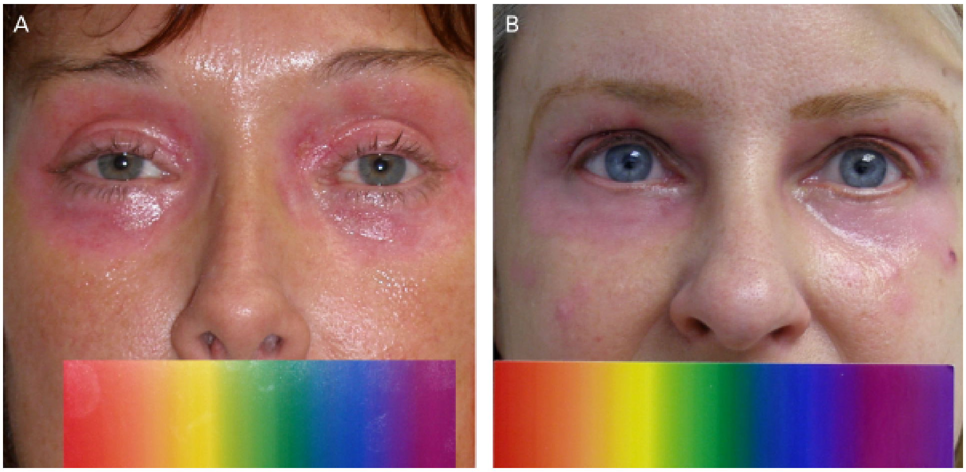

Figure 2. These patients were treated with two passes with a fluence of 6 J/cm^2, high-density (6 = 35% overlap) CO_2 laser in the lower eyelids. No debriding was performed. Patient A is shown 7 days postlaser and Patient B is shown 9 days postlaser. (The upper lids were treated with a single pass at the same settings.)

such as the perioral area and cheeks regions. Figure 4 illustrates a typical example of three nondebrided passes at 6 J/cm^2, density 6 (upper and lower eyelids were treated with one and two passes, respectively). All photos were taken by the author/surgeon with the same 7-megapixel camera, using the same settings, lighting, focal length, and background. A color spectrum was used in some of the pictures later in the study to better quantify the hue, saturation, and intensity of the various before and after photos. Some patients also underwent concomitant cosmetic surgery procedures such as brow lift, blepharoplasty, face-lift, liposuction, and facial implant placement. In patients with undermined flaps, the central oval of the face was treated with the higher fluence, density, and number of passes but subcutaneous forehead and face-lift flaps were treated with a single nondebrided pass of the same fluence, but the density was reduced to a setting of 4 (20% overlap). In examining the postlaser images in Figures 2 and 4, experienced laser surgeons can recall on experience and appreciate the fast resolution of postlaser erythema

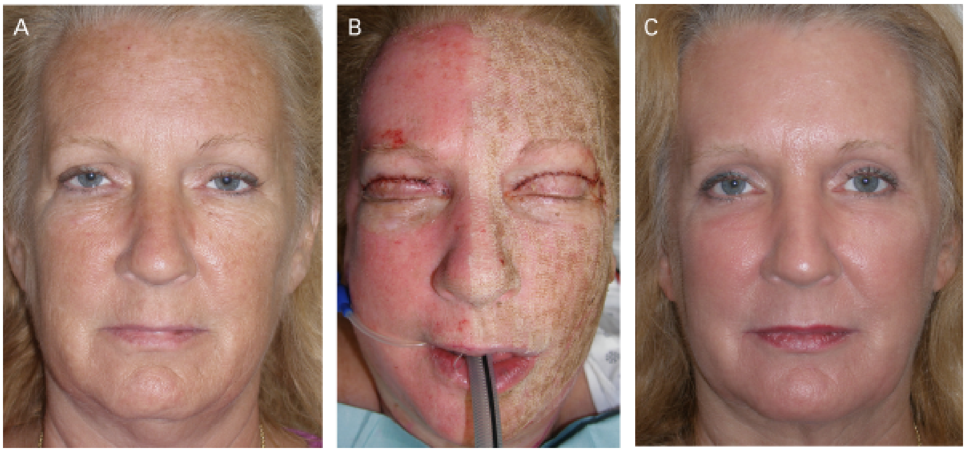

Figure 3. This patient was treated with two high-density passes (6 J/cm^2, density 6). The patient's right side was debrided after each pass and the left side was not debrided at all. The patient is shown prelaser (A), immediately postlaser (B), and 1 month postlaser (C). No untoward effects were seen on the nondebrided side.

Figure 4. This patient with facial aging and actinic damage is shown preoperatively (A), immediately postlaser with three high-density, (6 J/cm^2, density 6) nondebrided passes (B), 13 days postlaser (C), and 6 weeks postlaser (D).

and faster healing (although qualitative) when compared to patients treated with saline gauze debriding between passes.

In this study, a large number of multipass patients were followed clinically and photographically. The vast majority of these cases had less pain, healed faster, and experienced faster resolution of erythema. One hundred percent of these cases had shorter operative times, fewer postoperative visits, and much easier wound care when compared to a decade of experience with debriding techniques. Not debriding and using an open wound care technique simply made the entire experience easier for the patients, surgeon, and staff. What is most important, as well as the primary finding of this study, is the fact that using the nondebriding technique with a high-energy, high-density (6 J/cm^2, density 6), multipass (two to three passes) CO_2 laser resurfacing is a safe technique.

Histologic Analysis

From the previous animal and human literature studies and related dogma of LSR, this author mistakenly had the idea that three passes of moderate to high fluence with a high-density setting would ablate tissue to the level of the reticular dermis. After carefully reviewing the literature, penetration depth is notoriously variable and imprecise. There is enough thermal damage to the tissues that shrinkage and contracture blurs the margins of the measured ablation crater. Many studies measure the ablation depth from the top of the epidermis immediately adjacent to the spot of maximal laser destruction to a point which residual underlying tissue was present. Because of thermal shrinkage, these points are highly arbitrary, which explains the widely variable data from study to study.[30]

Fitzpatrick and coworkers[26] demonstrated that thermal necrosis is only well controlled with single-pulse vaporization. In their study, skin samples from surgical excisions were treated by means of an Ultrapulse carbon dioxide laser (Coherent, Santa Clara, CA) at 250 and 500 mJ per pulse with a 3-mm collimated beam and a repetition rate of 10 Hz. A total of 70 treatment areas were performed. Blinded analysis of the histologic effects of single-pulse, double-pulse, and triple-pulse vaporization after 1 through 10 passes was undertaken. Their results showed that a plateau of vaporization was observed after 3 passes at both 250 and 500 mJ whether single-, double-, or triple-pulse vaporization was used. This plateau occurs at approximately 100 to 25 μm from the skin surface. There is a direct linear increase in the depth of thermal necrosis both with the number of pulses stacked and with the number of passes. Most of the early studies were performed with straight collimated 3-mm handpieces and not CPGs. Burkhardt and Maw[22] corroborated this in 1997 with a study on breast and eyelid skin. They stated that the ultrapulsed CO_2 laser at 300 mJ and a density of 4 would remove the entire epidermis and papillary dermis and that up to 16 passes caused an ablation depth between 250 and 400 μm. This study was done while debriding between passes with moist saline gauze. They also stated that after 3 to 4 passes (and up to 16 passes) the depth of injury extended only slightly but with progressively less tissue removal. They applied this clinically by resurfacing one-half of actinic damaged perioral skin with four passes and the other side with 10 passes. Both sides healed uneventfully and they could not tell a difference of either side after healing. They concluded that since this damage only extended into the superficial reticular dermis and not the adnexa that a wide margin of safety existed when using the CPG. It should be noted that this study utilized breast tissue that was not actinically damaged and eyelid skin, which is among the thinnest skin on the body. One must keep in mind that the thickness of the papillary dermis varies greatly depending on the skin site and that these measurements cannot necessarily be applied to extremely actinically damaged and elastotic facial skin.

In reviewing the literature for a more clinically relevant study, a 1999 article by Grover and coworkers[30] performed a laser ablation depth study on humans. These authors studied the histologic depth of thermal damage using the CPG with varying density settings and passes. Preauricular (sun-exposed) and postauricular (sun-protected) skin slated for removal on face-lift patients was treated using 12 sites per patient. Each region was exposed to 1, 2, and 3 passes of 300 mJ (7.5 J/cm^2) and a spot size of 2.25 mm with the CPG. One side was treated with a density of 5 (30% overlap) and the other side was treated with a density of 9 (60% overlap). The charred skin was removed between passes with moist saline gauze. All biopsies were evaluated by a blinded histopathologist. Histologic examination of the treated test sites consistently demonstrated that one pass at these settings obliterated most or all of the epidermis with minimal invasion into the papillary dermis. Test sites treated with two or three passes resulted in increased cumulative depth of penetration and thermal injury into the papillary dermis. None of the relevant data points extended into the reticular dermis. As expected, the depth of penetration was greater with the higher density on both sides. The depth of injury was also greater on the postauricular sites (sun-protected skin). Another finding was that fewer passes at a higher density setting did not achieve the same depth of penetration as more passes at a lower density setting. At a density of 5, the preauricular site showed that one pass produced a tissue injury to an average of 41 μm, two passes to 52 μm, and three passes to 86 μm, for a cumulative depth of 179 μm. At a density of 9, the first pass average depth was 43 μm, for two passes it was 76 μm, and three passes showed a depth of 121 μm, for a cumulative depth of 240 μm.

Since most practitioners do not use 60% overlap (density 9), a density of 5 (30% overlap) is most clinically relevant and, in summary, one pass will ablate most or all of the epidermis, two passes will enter the papillary dermis, and three passes will produce diffuse injury to the papillary dermis. This has been similarly confirmed in other human CPG studies.[31–33]

This author's histologic study was randomly performed on five study patients by lasering skin on the preauricular regions of face-lift patients. The Encore Ultrapulse laser (Lumenis Inc.) was set at 80 mJ (6 J/cm^2) with a density of 6 (35% overlap). This new laser has a spot of 1.3 mm compared with the 2.25-mm spot size of the older 5000C Lumenis laser. For this reason, the mJ settings are lower to attain the same fluence of the older laser. In the author's practice, the clinical response of the older 5000C laser set at 300 mJ, 60 W and a density of 6 translates to about 80 mJ on the newer Encore laser. Using the Encore laser (with the 80 mJ setting at a density of 6 and a square pattern size 9), the preauricular skin was treated on one side by lasering three passes without debriding between passes. The contralateral preauricular area was lasered at the same settings for three passes but the char was wiped with saline gauze after each pass. Excisional biopsies were taken on both sides and processed at a private laboratory and read by a blinded dermatopathologist.

Immediate Postlaser Debride and Nondebride Histology

The following cases were typical of those biopsied for this study: Case 1 is illustrated in Figures 5 and 6 and Case 2 is illustrated in Figures 7 and 8. In reviewing the histologic specimens in this study, as predicted, multiple-pass, high-density, high-energy LSR (6 J/cm^2, density 6) will ablate the entire epidermis and penetrate the dermis to variable depths. This is based on such variables including the patient, the area and type of skin treated, the laser fluence, the number of passes, and the amount of actinic damage of the treatment site. This level of damage is also consistent with previous studies using similar settings and the CPG.

In the five patients that were biopsied in this study, the thermal damage was limited to the papillary dermis and no thermal damage came close to the reticular dermis in any patient, whether the char was debrided after laser passes or not. The extent of thermal damage at the same settings (whether debrided or not) ranged from 85 to 250 μm. This implies that in this study, three passes at 6 J/cm^2 and a density of 6 can be overlapped without debriding and achieve clinical efficacy of skin rejuvenation with a wide margin of safety.

Pros and Cons of Nondebriding

Advantages

Various colorimetric techniques are available to evaluate postresurfacing erythema and its resolution but were beyond the confines of this study.
This study involved a more clinically qualitative

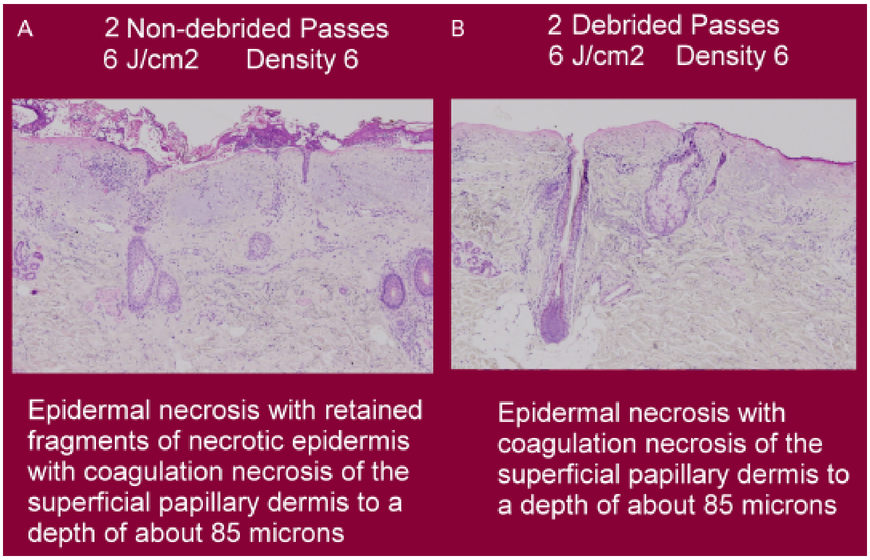

Figure 5. (A) Histologic result of two aggressive passes without debriding between passes showing epidermal necrosis. The approximate depth of the thermal injury is 85 μm into the superficial papillary dermis. (B) Specimen from the same patient treated with the same laser and settings but with the char debrided after each pass. The average depth of the thermal damage is almost exactly the same as the nondebrided specimen (85 μm) shown in A. Original magnification, ×4.

observation of erythema resolution and postoperative pain. Although this method is less scientific, experienced and astute laser practitioners have a "gestalt" and are aware of faster or slower postlaser erythema resolution and pain. The nondebrided patients, as a group, had less postlaser discomfort and their postlaser erythema resolved significantly faster than the hundreds of full-face laser patients treated by this author over the past decade. Admittedly, this is qualitative opinion, but one that is based on a busy and diverse CO_2 laser experience. Although difficult to quantify in this particular study, to ignore these positive findings goes against the grain of observational clinical medicine and surgery. The histologic portion of this study is more scientific and the qualitative portion can be construed as equally

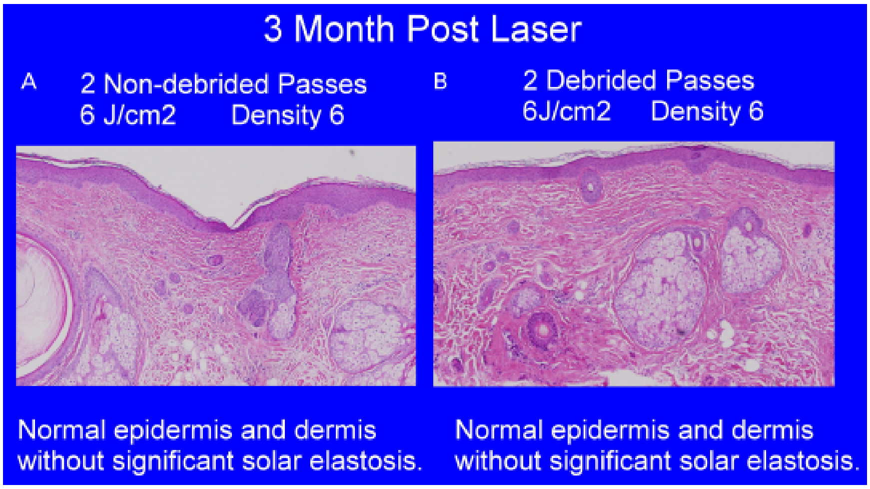

Figure 6. (A and B) Same patient's histology as shown in Figure 5. Three months post-LSR, there is normal epidermis and dermis. There has been significant improvement of the solar elastosis shown in Figure 5. Original magnification, ×10.

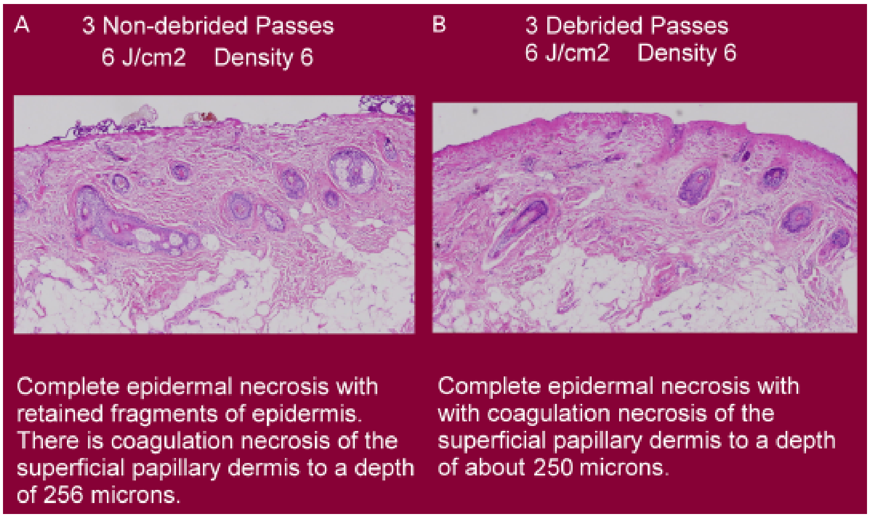

Figure 7. (A) Histologic results of three aggressive laser passes without debriding between passes. The depth of the thermal injury is approximately 256 μm. (B) Specimen from the same patient using the same laser and settings but with debriding after each pass. It is notable that the average depth of tissue injury is almost exactly the same in both specimens (A and B) regardless of debriding or not. Original magnification, $\times$ 4.

relevant to other practitioners if repeatable in their practices.

Other qualitative observations were a greater acceptance of aggressive laser resurfacing by the author, the staff, and the patients. All patients also had fewer follow-up appointments for dressing changes, wound care, etc., and were only seen at 1 to 2 weeks postprocedure.

As mentioned previously, performing multipass lasering without debriding allows a much faster surgical procedure as the multiple time-consuming steps of debriding the entire face (sometimes three to four times in a single procedure) were eliminated. Finally, although a small advantage, the messy strewing of debrided skin about the surgical site, floor, and patient is also eliminated in the nondebriding technique.

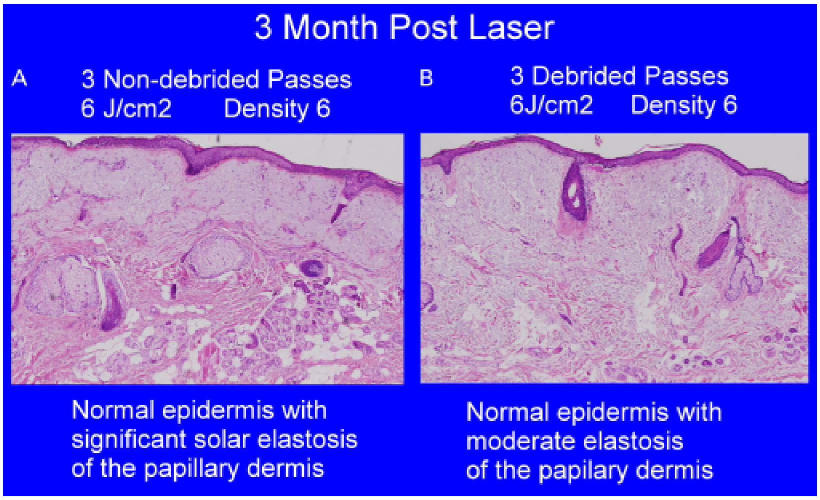

Figure 8. (A and B) The same patient's histology as shown in Figure 7. Three months post-LSR, there is normal epidermis but persistent solar elastosis despite the depth of penetration (Figure 7). Original magnification, $\times$ 4.

Disadvantages

Very few drawbacks were noted with the high-density, multipass, nondebriding technique. It would suffice that this procedure should not be attempted by the novice laser surgeon as the clinical road leading to this technique is curvy and full of learning. It has been said that to learn "the tricks of the trade, one must first learn the trade." To appreciate the safety and effects of this aggressive method of LSR, one must understand what happens to the various skin layers with single passes and debriding techniques, as well as what method of postoperative care works best in his or her practice. It is suggested that nondebriding technique be attempted on smaller subunits of the face to gain experience and confidence before the novice practitioner attempts full-face, high-fluence multipass, non-debrided treatment.

One relative drawback of the nondebriding technique is that fact that it is more difficult to judge the clinical treatment end point based on the color and desiccation level of the dermis. The described "chamois" color end point is not visible through the undebrided char, and it is more difficult to determine skin desiccation as the char, again, obscures the underlying tissue.

Conclusion

Previous studies have detailed nondebriding techniques of LSR in animals and humans. These human studies, however, did not utilize multipass, higher-fluence, high-density coverage of the entire face without debriding. This appears to be the first human study that details a large number of nondebrided LSR treatments utilizing moderately high fluence and high densities without debriding between two and/or three consecutive passes and employing open wound care.

Based on the 90 full-face laser patients treated in this study with the nondebriding technique, 47 patients were treated with a single pass, 33 were treated with two passes without debriding, and 10 patients were treated with three nondebrided passes using moderately high fluence and density for each pass. This study also included 66 patients with two nondebrided passes in the lower eyelids.

All patients had decreased operative time and simpler postoperative care. No patient in this study developed any significant postlaser complication such as hypertrophic scarring using the nondebriding technique. Qualitatively, the two- and three-pass nondebrided patients had less postoperative pain, and the postlaser erythema resolved faster than in the hundreds of patients treated by this author over the past decade.

Three high-energy passes at 6 J/cm^2 and a density of 6 can be consecutively overlapped in appropriate patients without debriding, and no significant negative differences are seen when compared to traditional debriding techniques. This nondebriding method can safely achieve skin rejuvenation with a wide margin of safety as well as shorten treatment times and simplify wound care, postoperative pain, and patient acceptance.

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