An Ultrastructural Comparison of Mechanical Dermabrasion and Carbon Dioxide Laser Resurfacing in the Minipig Model

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Objective: To compare the histological and ultrastructural changes in skin collagen with mechanical dermabrasion and pulsed carbon dioxide laser resurfacing in the minipig model.

Setting: Academic medical center.

Subjects: Yucatan minipig animal skin model.

Main Outcome Measures: Comparison of light microscopic and ultrastructural (electron microscopic) changes in the skin following the 2 resurfacing modalities.

Results: No significant difference in collagen histological characteristics or ultrastructure was detected between the 2 comparison groups.

Conclusions: When mechanical dermabrasion or pulsed carbon dioxide laser resurfacing is used with similar-depth injury to the dermis in this model, the histological changes seen via light microscopy and ultrastructural changes seen via electron microscopy are similar between the 2 treatment modalities.

Carbon dioxide laser resurfacing to treat both scarring and actinically damaged skin has recently revolutionized the resurfacing literature. The proponents of laser resurfacing over mechanical dermabrasion assert that the laser technique is more exacting, more “user friendly,” safer, and more consistent than its counterpart, mechanical dermabrasion. Furthermore, proponents of the laser technique claim that it leads to better results in terms of improvement in fine wrinkles and tightening of the underlying dermis.

Recent reports discuss electron microscopy of the dermis following various resurfacing techniques (mechanical dermabrasion and chemical peel). It has been suggested that the changes in collagen fiber ultrastructure may account for much of the improvement in scarring or wrinkling with any given resurfacing technique. However, to our knowledge there is no comparison study in which the effects of mechanical dermabrasion are directly compared with the effects of laser resurfacing in a controlled model. In this study we compared the ultrastructural characteristics of similar-depth injuries using the carbon dioxide laser vs mechanical dermabrasion in the minipig model.

RESULTS

Light microscopic evaluation of biopsy specimens taken immediately after the procedure revealed similar full-thickness loss of the epidermis and papillary dermis. By days 7 to 10, complete regeneration of epidermis occurred. The papillary dermis at this stage was characterized by edema, vascular ectasia, extravasated erythrocytes, and variable infiltrates of spindled and inflammatory cells. By 1 month, the papillary dermis was expanded and composed of fine collagen fibrils. At 3 months, all specimens revealed only discrete areas of thickened papillary dermis. Collagen fiber density and organization were similar between control and treated specimens by 3 months as indicated by trichrome staining. Verhoeff–van Gieson staining revealed minimal development of dermal elastic fibers in any of the specimens. These findings correlate with the absence of photodamage in the skin of the minipigs.

Electron microscopic data were analyzed in terms of collagen fiber D-band periodicity (a measure of collagen fiber density) change and collagen fiber diameter change before and after the respective resurfacing techniques. Collagen fiber D-band periodicity prior to resurfacing averaged 70.2 nm, with an average fiber diameter of 87.2 nm. Average decrease in periodicity at 180 days for the dermabrasion sites was 9.0 nm. It should be noted that the controlled periodicity and diameter were consistent between skin specimens on the same pig and between animal specimens. The decrease for the
MATERIALS AND METHODS

Institutional guidelines regarding animal experimentation were followed after study approval by the institutional animal research committee. Two Yucatan minipigs were used for the study. Each minipig provided multiple sampling areas for the respective resurfacing techniques. In particular, regions on the backs of the pigs were tattooed at the beginning of the study to delineate 2 control regions, 2 regions for laser resurfacing, and 2 regions for mechanical dermabrasion. Dermabrasion was carried down to the superficial dermis, as evidenced by punctate bleeding. Laser resurfacing was performed using a carbon dioxide laser (Coherent UltraPulse 5000C, Medical Alliance Incorporated, Glendale, Calif) at a power setting of 450 mJ at 10 W and a density setting of 5 (30% overlap) using the computerized pattern generator with an estimated frequency of 22 pulses per second. Three total passes were performed to attain a similar-depth injury as with dermabrasion, evidenced clinically by a light chamois color in the resurfaced dermis. The resurfaced region was wiped with a damp gauze to remove any eschar and carefully dried prior to proceeding with the subsequent pass. Similar depth of injury was confirmed using light microscopy.

Biopsy specimens of the respective regions were then obtained at days 0 (immediately following the procedure), 3, 7, 10, 14, 90, and 180 following the procedures. Early biopsy specimens were taken to ensure similar depth of injury, evidenced by light microscopic study using hematoxylin-eosin and trichrome staining. Biopsies were accomplished using a full-thickness punch technique. Previous biopsy sites were avoided within the resurfaced regions. Appropriate specimens were submitted for light and electron microscopic study.

Laser sites at 180 days was 12.4 nm. Comparing the periodicity decrease in the laser sites with the decrease in the dermabrasion sites, the difference was not statistically significant using an analysis of variance of the data (P = .09). Similarly, results at 180 days for the increase in diameter in the fiber were not significantly statistically different (P = .47). Also, there was no statistically significant difference found at 90 days for the 2 specimens (P>.05). The control data for all the respective values did show a statistically significant decrease in periodicity and diameter within the dermabrasion sites (P<.05) and laser sites (P<.05), both at 90 and 180 days. 

Figure 1. Electron photomicrograph of superficial dermal collagen of a minipig 180 days following dermabrasion. Note consistent collagen fiber polarity and D-band periodicity and diameter (×100 000).

Figure 2. Electron photomicrograph of superficial dermal collagen of a minipig 180 days following dermabrasion. Note changes consisting of decreased polarity, smaller diameter, and shorter periodicity relative to the control dermis in Figure 1 (×100 000).

Figure 3. Electron photomicrograph of superficial dermal collagen of a minipig 180 days following dermabrasion. Note changes consisting of decreased polarity, smaller diameter, and shorter periodicity relative to the control dermis in Figure 1 (×100 000).

COMMENT

Mechanical dermabrasion and the newer technique of carbon dioxide laser resurfacing both are effective in improving fine facial wrinkles and scarring. The widespread recent popularity of carbon dioxide resurfacing among various specialists suggests that, potentially, laser resurfacing provides more effective results than its mechanical counterpart. The various reasons for this phenomenon may include operator-dependent factors that are independent of the given technique used. Mechanical dermabrasion is a subjective mechanical contouring of the outer layers of the skin. The technique is difficult to master and requires observing multiple procedures carried out by an experienced surgeon prior to proceeding with dermabrasion surgery. Laser resurfacing, on the other hand, is relatively user friendly for the inexperienced surgeon, although the scattered problems of scarring secondary to laser use emphasize that this technique requires both observation and training prior to performing the procedure safely.

In this study, in an attempt to better delineate the differences between laser abrasion and mechanical dermabrasion, we compared the ultrastructure of the collagen fiber, specifically focusing on the changes in collagen periodicity and diameter with resurfacing. If collagen remodels following any resurfacing procedure, the newly organized collagen matrix generally is populated by collagen fibers of shortened periodicity and decreased diameter. This presumptively explains (perhaps partially)
the skin tightening and improvement in fine wrinkling obtained after resurfacing.

In the present study we were unable to show statistically significant differences in these ultrastructural changes with carbon dioxide laser resurfacing and mechanical dermabrasion at a similar depth of injury, although our data did show a trend of shorter periodicity with the laser vs mechanical dermabrasion. Similarly, Fitzpatrick et al. compared chemical peel, dermabrasion, and pulsed carbon dioxide laser resurfacing using light microscopy and clinical inspection and found similar results between the resurfacing modalities. This may suggest that the 2 techniques should lead to similar clinical results when carried out to similar depths of injury. Alternatively, perhaps other factors are involved that may explain the improved clinical results reportedly obtained with laser resurfacing. These factors may include other micromolecular phenomena leading to improved skin texture. However, as suggested previously, other differences in the techniques may explain the increasingly widespread popularity of laser resurfacing. These differences may be technique-specific and involve the slope of the learning curve involved with either procedure.

While sampling error is always a concern when examining any phenomenon ultrastructurally, the statistical data between pigs, as well as specimens within the same pig, suggested relative consistency in our measurements.

While it has been suggested that electron micrographic ultrastructural changes in the collagen fiber may be used as a marker in the future for relative skin tightening and wrinkle improvement with various resurfacing techniques, perhaps the skin changes are the effect of multiple factors, 1 of which may be collagen fiber shortening and thickening. For example, changes in the ground substance, especially in terms of changes in relative glycosaminoglycan content, may partially explain improvement in skin texture with the laser vs dermabrasion. Such unexplained phenomena as well as individual, user-dependent variables may also contribute to relative improvement using one technique vs another for skin resurfacing.

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REFERENCES