Core Innovations in Skin Rejuvenation: A Systematic Review of Microcoring Technology

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BACKGROUND Microcoring is a novel, minimally invasive technology for skin rejuvenation that uses hollow needles to remove full-thickness skin cores.

OBJECTIVE To review the current evidence on the outcomes and safety of microcoring and identify areas for future research.

PATIENTS AND METHODS/MATERIALS A PRISMA-compliant systematic review was conducted using the search strategy "micro-coring' OR "microcoring" across PubMed, Embase, Web of Science, and Cochrane. Risk of bias and quality assessment were conducted.

RESULTS Eight studies were included: three preclinical in vivo porcine studies and five clinical studies involving 112 patients. The studies evaluated various microcoring designs, differing in needle size, depth, number, and treatment density. Current evidence indicates that microcoring improves skin quality through mechanisms involving tissue removal, skin tightening, and epidermal and dermal regeneration/remodeling. Clinically, microcoring has been most commonly investigated to treat facial rhytids, with emerging applications for enlarged facial pores and acne scars. Studies report mild pain and trace-to-moderate bleeding during the procedure, and trace-to-moderate postprocedure adverse skin effects.

CONCLUSION Microcoring demonstrates promising outcomes in improving skin quality and seems to be well-tolerated and safe. Studies with larger patient cohorts, longer follow-up, comprehensive histological analyses, and comparisons with other minimally invasive techniques are needed to confirm outcomes and refine strategies.

Microcoring has emerged as an innovative, minimally invasive treatment for skin rejuvenation.[1] This technology uses modified hollow needles to remove full-thickness skin cores leading to skin tightening and skin quality improvement (Figure 1).[1] The size of the skin cores removed depends on the needle's inner diameter and length. The mechanisms of microcoring are based on the principles of fractional photothermolysis, but operates without the use of thermal energy, potentially minimizing adverse effects associated with heat-induced injury.[2] Microcoring differs from microneedling in that tissue is excised instead of only punctured. Currently, microcoring is most commonly used for treating rhytids in the mid-to-lower face, following FDA clearance of a device for this indication in 2021.[3]

Microcoring was initially described by Fernandes and colleagues in 2013.[1] Since then, several studies have investigated the technology's safety and outcomes. However, studies have varied in design, needle characteristics, treatment density, treatment indication, and outcomes assessed. Given the interest in minimally invasive approaches for skin rejuvenation, a comprehensive synthesis of the current evidence on microcoring technology may help better realize its role in modern dermatology and plastic surgery. Therefore, this systematic review of the literature aims to (1) evaluate the preclinical and clinical outcomes of microcoring, (2) assess the safety profile and adverse effects, and (3) identify knowledge gaps and areas for future research.

Methods

Search Strategy

Publication review was conducted on PubMed, Excerpta Medica dataBASE (EMBASE), Web of Science, and Cochrane Library in October 2024 according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.[4] The following search strategy was used: (micro-coring) OR (microcoring). For the included studies, references were screened for relevant articles.

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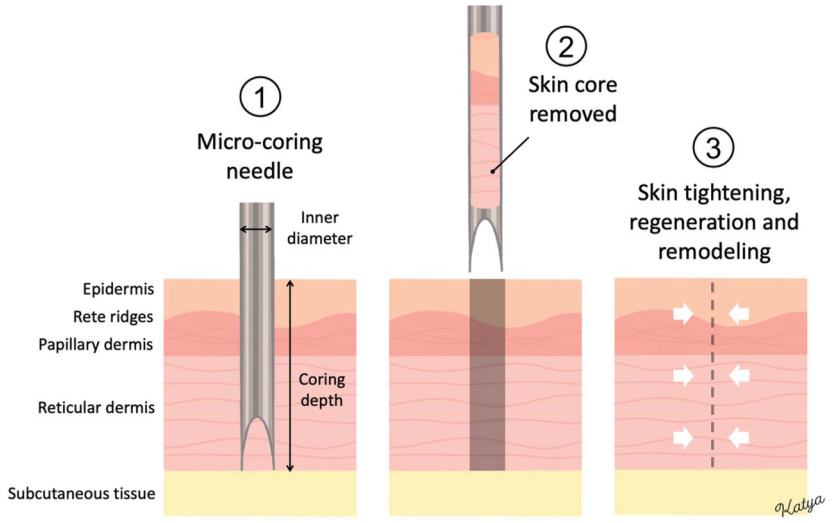

Figure 1. Microcoring technology. (1) Hollow microcoring needles have an inner diameter and length corresponding to the size of the full-thickness skin cores to be removed. (2) During treatment, serial skin cores are mechanically excised at a treatment density determined by the number of cores removed over the total surface area of the treated region. (3) Skin core removal promotes skin tightening and skin regeneration.

Selection Criteria

All published articles since the databases' date of inception until the search date were identified and screened. Articles were excluded if they were communications, reviews, abstracts, or if no full text could be obtained. Studies that did not pertain to microcoring for skin treatment were also excluded. There were no language restrictions. All identified articles were independently screened by reviewers using Rayyan software (Rayyan, Cambridge, MA).[5] Discrepancies were discussed by the reviewers, and if needed, resolved by the senior author serving as an adjudicator.

Data Extraction

Data for included articles were collected independently by the reviewers using Microsoft Excel (Microsoft Corp., Richmond, WA). Variables included publication year, author, study design, number of animals for preclinical studies, number of patients for clinical studies, area treated, treatment indication, microcoring design (needle number, size, depth, and treatment density), outcomes, adverse effects, and follow-up duration.

Risk of Bias and Quality Assessment

Two reviewers independently evaluated the risk of bias (ROB) of preclinical studies using the Systematic Review Centre for Laboratory animal Experimentation (SYRCLE) ROB tool.[6] For clinical studies, the Cochrane ROB 2 tool was used to assess randomized controlled trials, the Methodological Index for Non-Randomized Studies (MINORS) instrument for nonrandomized studies, and the Joanna Briggs Institute (JBI) critical appraisal tool for case series.[7–9] If needed, discrepancies were resolved by the senior author. If multiple study cohorts were discussed in a single article, the ROB was assessed separately.

Results

The search strategy yielded 226 articles. After screening, eight articles, published between 2013 and 2024, were included. These consisted of three preclinical studies involving 10 porcine models (see **Supplemental Digital Content**, Table 1, http://links.lww.com/DSS/B619) and five clinical studies involving 112 patients (see **Supplemental Digital Content**, Table 2, http://links.lww.com/DSS/B619).

Preclinical Studies

The microcoring technology was first described by Fernandes and colleagues[1] in 2013 who used an in vivo porcine model to compare the safety and efficacy of microcoring needles against standard hollow hypodermic needles, solid needles, and untreated controls. Sixty-four skin sites, each measuring 6.5 cm^2, were assigned to a needle group and treated with 20% or 40% treatment density. The microcoring needles were 25-gauge or 23-gauge and affixed to a plastic base to form a four-needle microcoring device. All treatment groups initially exhibited erythema with serous exudate, healed within 2 weeks, and showed no signs of macroscopic scarring. There were no reported adverse events. Histological analysis revealed that at 1-month postprocedure, epidermal and papillary dermal thickness in microcoring sites were significantly greater than other treatment groups, showing an 87% and 96% increase, respectively, compared with controls. By 3 months, microcoring sites also exhibited a significantly greater mean collagen content compared with other groups, with an 89% increase over controls. The authors also noted more prominent, newly formed, horizontally organized elastin, and increased undulations of rete ridges; however, these outcomes were not quantified. No significant differences in skin surface area reduction were found between groups, and needle gauge was not significantly associated with a change in skin thickness, collagen content, or surface area reduction.

The second preclinical study, published by Russe and colleagues[10] in 2016, evaluated microcoring technology in five in vivo porcine models. A total of 116 skin sites, each measuring 3 cm^2, were treated with microcoring alone,

microcoring with immediate directed wound closure using an adherent elastic Tegaderm dressing, standard hollow hypodermic needles with Tegaderm dressing, or were assigned to an untreated control group. All needles were 19-gauge, and the treatment density was 10%. The microcoring needles were designed to have two symmetrical prongs and were attached to a vacuum system. All treatment groups healed within 1 week without evidence of erythema or macroscopic scarring at 1 month. There were no reported adverse events. At 1 month, sites treated with microcoring and directed wound closure showed a statistically significant 9% reduction in skin surface area, with the direction of skin tightening in that of the applied dressing, irrespective of skin tension line orientation. By contrast, sites treated with microcoring alone or with standard hypodermic needles showed a nonsignificant reduction in skin surface area of 3%. Histological analysis showed all microcoring sites to be completely reepithelialized by 1 week. At 1-month, a normal dermal matrix architecture was established with identifiable puncture sites. The authors did not report on epidermal or dermal thickness and provided no comparative histological data.

The third and most recent preclinical study was published in 2023 by Ramot and colleagues[11] and further evaluated microcoring in four in vivo porcine models. Forty-eight skin sites were treated with microcoring using a robotic device (AI.ME, Venus Concepts Inc., San Jose, CA) equipped with six rotating (4,500 rpm) microcoring needles, each with a 0.74 mm diameter and 3 mm depth, and integrated with a vacuum system. Tegaderm dressings were applied over the treated sites. An additional positive control site consisted of microcoring without Tegaderm dressing, and a negative control consisted of an untreated site. On the day of treatment, erythema scores for all treatment groups ranged from 3 (moderate) to 4 (severe), and edema scores ranged from 1 (very slight, barely perceptible) to 2 (well-defined). These signs gradually decreased starting at 2 to 3 days after treatment and were resolved at the 1-month evaluation. There were no reported cases of scabbing, crusting, erosions, burns, purpura, vascular necrosis, hyperpigmentation, hypopigmentation, or clinical scarring in any of the experiments. Histological evaluation revealed progressive reepithelialization with a transient focal increase in epidermal thickness, representing hyperplasia, and mature dermis at the core sites.

Clinical Studies

The first clinical study was published in 2021 by Pozner and colleagues[12] who conducted three prospective, single-blinded, randomized controlled trials to evaluate the safety and outcomes of a microcoring device (Ellacor, Cytrellis Biosystems, Inc., Woburn, MA). Female and male subjects were included with an age range between 34 and 71 years and with Fitzpatrick skin types I to V. The device consisted of a handpiece with a consumable needle cartridge and an integrated vacuum system. The first abdominal skin trial included 1 cm^2 sites in five patients undergoing abdominoplasty randomized to microcoring needle size (19- or 24-gauge) and treatment density (10% or 20%). The second trial was a short-term facial skin trial including 2 cm^2 preauricular sites of nine patients undergoing face-lift surgery randomized to needle gauge (22- or 24-gauge) at a fixed treatment density of 10%. The third long-term facial skin trial included 2 cm^2 preauricular sites of 15 patients not undergoing any surgery randomized to needle gauge (22-, 24-, or 25-gauge) and treatment density (2.5%, 5%, 7.5%, or 10%). In all three trials, mild pain and trace-to-moderate bleeding were noted at the time of the procedure. In the abdominal skin trial, patients experienced trace-to-mild ecchymosis, edema, crusting, roughness, dryness, and inflammation up to 1-month postprocedure, and trace-to-mild redness and hyperpigmentation up to 3 months. In the short-term facial skin trial, trace ecchymosis, crusting, and roughness were seen up to 2 weeks, with trace edema, redness, dryness, inflammation, and hyperpigmentation up to 1 month. In the long-term facial skin trial, trace roughness, dryness, and inflammation were seen for up to 1 week, trace redness up to 2 weeks, and trace hyperpigmentation up to 3 months. One adverse event, a superficial wound infection, was observed in the short-term facial trial and resolved without intervention. Histological analysis at 3 months showed a significant increase in skin thickness compared with baseline and untreated control sites in all three trials. In the abdominal skin trial, there was an absence of microscopic scar tissue. Evaluation of skin tightening in the short-term facial skin trial demonstrated a significant 9.4% reduction in skin surface area compared with baseline and control. Aesthetic outcomes in the long-term facial skin trial showed that both patient and investigator Global Aesthetic Improvement Scale (GAIS) scores reached an average score representing a "very much improved" outcome. The long-term facial skin trial also revealed absence of clinical scarring using the Manchester Scar Scale.

In 2022, Gfrerer and colleagues[13] conducted a prospective multicenter clinical trial similarly evaluating the Ellacor (Ellacor, Cytrellis Biosystems, Inc.) microcoring device for the treatment of mild-to-moderate wrinkles in the mid-to-lower face. The study included 51 patients who underwent two or three treatment sessions. Most patients were female with a mean age of 62.9 (±5.92) years. Fitzpatrick skin types ranged from I to IV. The microcoring device consisted of three 22-gauge needles with coring depths between 3 and 5 mm. Treatment densities of 6.5%, 6.7%, 7.9%, or 8.5% were used with a minimum core count of 6,000 microcores per treatment. Procedure bleeding was mild in most cases (78%), and the mean pain intensity ranged between 1.3 and 2.8 of 10. By 1-month postprocedure, fewer than 5% of patients had moderate dryness, erythema, or hyperpigmentation, all of which resolved by 3 months. There were four adverse device events, including periorbital ecchymosis, malar paresthesias, prolonged redness, and persistent needle marks, none of which were considered serious and all of which resolved by the end of the study period. At 3-months postprocedure, an independent review panel found a significant improvement in the average Lemperle Wrinkle Skin Severity (LWSS)

and GAIS scores compared with baseline. Specifically, 89.7% of patients had improvements in GAIS. Postprocedure photographs were correctly identified by the panel in 84.2% of cases, and 85.6% of patients endorsed satisfaction with their outcomes. No histological studies were conducted.

A case series by Yi and colleagues[14] in 2023 investigated the use of the N-Derm (N-finders, Co., Ltd., Seoul, South Korea) microcoring device for treating enlarged pores in the cheeks of three patients. Two patients were female and one was male with ages 30, 31, and 32 years. The hand-held device consisted of a single 0.5-mm diameter robotic rotating microcoring needle. The authors described removing 40 to 50 full-thickness skin cores in each patient followed by elastic adhesive dressings for 1 week. During the procedure, two patients experienced minor bleeding, while one experienced moderate bleeding. Pain intensity scores ranged between 2 and 3 of 10 during the procedure which resolved the following days. The healing profile was favorable with no cases of erythema, edema, folliculitis, hyperpigmentation or hypopigmentation, and no serious adverse effects. At the final 1-month follow-up, facial pores were graded by dermatologists as improving either from "severe" to "mild" or from "mild" to "almost clear." On a satisfaction scale of "very satisfied," "satisfied," or "disappointed," two patients reported being "very satisfied," while one was "satisfied." The authors did not mention evaluating scarring, and no histological analyses were performed.

The same group investigated the use of the N-Derm (N-finders, Co., Ltd.) microcoring device for the treatment of facial acne scars in 2024.[15] Their case series included three patients with icepick and boxcar scars on the cheeks and glabella. One female and two males aged 32, 46, and 49 years were included. The size of the rotating needle in this study was larger, 1 mm in inner diameter, and was used to target individual acne scars. Although not quantified, fewer cores were removed per patient compared with their previous study for facial pores, and each coring site was closed with 7-0 nylon sutures and elastic adhesive dressings for 1 week. Like the previous study, procedure bleeding ranged between mild-to-moderate, and patient-reported pain intensity between 2 and 3 of 10. At the final 2-month study follow-up, there were no cases of persistent pain, erythema, edema, folliculitis, or dyspigmentation. When analyzing before-and-after photographs, one dermatologist graded all the acne scars to have improved in appearance from "severe" to "mild," while a second dermatologist graded all the acne scars to have improved from "mild" to "almost clear." On a satisfaction scale of "very satisfied," "satisfied," "disappointed" or "very disappointed," two patients reported being "very satisfied," and one patient was "satisfied." The study did not report on the occurrence of any new scarring, and no histological analyses were conducted.

Most recently, Carruthers and colleagues[16] in 2024 conducted a retrospective cohort study of 26 patients evaluating the outcomes perioral microcoring (Ellacor, Cytrellis Biosystems, Inc.) with face-lift and neck-lift surgery, versus matched control patients who underwent face-lift and neck-lift surgery alone. Most patients were older than 60 years with Fitzpatrick skin Types II to III. The microcoring device used 22-gauge needles at an average treatment density of 7% (range 5%–8%). At an average follow-up of 8.9 months, 3D imaging analysis revealed that patients experienced a significant 6.18% reduction in philtrum length whereas controls showed no significant change. Perioral skin quality assessed by blinded plastic surgeons using the Scientific Assessment Scale of Skin Quality (SASSQ) revealed significant improvements in skin elasticity and wrinkles in microcoring patients compared with baseline and controls, although with no significant changes in skin roughness, pigmentation, erythema, blemishes, or pore size. In addition, significantly more microcoring patients had improvements in GAIS scores from baseline compared with control patients. There were no cases of prolonged hyperemia beyond 3 weeks postprocedure, no patients developed scarring, and no adverse events were reported.

Risk of Bias and Quality Assessment

For preclinical studies, while SYRCLE's risk of bias tool does not provide a summary score, several domains were identified as having a high risk of bias.[7,17] The randomized clinical trial conducted by Pozner and colleagues[8] was classified by Cochrane as having some concern regarding bias. Nonrandomized studies demonstrated moderate-to-high quality, with MINORS scores of 20 of 24 for Gfrerer and colleagues and 13 of 16 for Carruthers and colleagues[18] There were no predefined cut-off scores for the JBI tool, but both case reports exhibited poor quality across most domains. Summaries of the risk of bias assessments are provided in **Supplemental Digital Content**, see Table 1, http://links.lww.com/DSS/B619.

Discussion

This is the first systematic review summarizing the current evidence on microcoring technology. The literature to date suggests that (1) various designs of microcoring have been investigated and shown to improve skin quality, (2) the procedure seems to be well-tolerated and safe, and (3) further research is needed to confirm treatment outcomes and compare microcoring with other minimally invasive treatment options.

Current preclinical and clinical evidence suggests that microcoring improves skin quality through multiple mechanisms, including tissue removal, skin tightening and epidermal and dermal regeneration and remodeling. The extent of skin tightening, or reduction in skin surface area, seems to be proportional to the coring/treatment density.[10,16] In addition, histological changes in both epidermal and dermal layers have been observed beginning as early as 1-month postprocedure showing increased thickness, higher collagen content, and improved architecture.[1,12] However, more long-term histological investigations are needed to confirm the biological effects of microcoring.

Furthermore, most clinical studies to date have used microcoring to treat facial rhytids; however, emerging evidence from small case series also suggests its potential role in treating enlarged facial pores and acne scars.[12,13,16]

Microcoring seems to be well-tolerated by patients, with mild pain and trace-to-moderate bleeding during the procedure. The technology seems to be safe, with most adverse effects being typical signs and symptoms associated with wound healing. These effects, such as redness, ecchymosis, edema, crusting, roughness, and dryness, occur within the first week postprocedure. Some cases of trace-to-mild redness and trace hyperpigmentation have shown to resolve by 3 months. However, the severity of adverse skin effects may vary based on treatment location, coring density, needle size, and depth, as well as individual patient factors such Fitzpatrick skin type and comorbidities. Larger patient cohorts with longer follow-up duration will help determine durability of results and treatment indications. The inclusion of more diverse patient populations, such as those with Fitzpatrick skin types V and VI, could also provide valuable insights into the technology's efficacy and safety across a broader demographic.

Various microcoring needle designs have been explored. Although most studies have used 22-gauge microcoring needles (corresponding to an inner diameter of 0.41 mm), needle sizes have ranged from 25-gauge (0.26 mm) to 17-gauge (1 mm). A pilot study suggested that clinical scarring occurs when the diameter of the skin cores removed is 0.5 mm or larger. This data helps guide microcoring needle design to minimize scarring potential.[19] However, none of the reviewed studies, including those with larger needle sizes, reported clinical scarring, and of the studies which conducted histological analyses, none reported fibrosis or microscopic scarring. The largest needle size reported had an inner diameter of 1 mm and was used in a case series for the targeted treatment of acne scars, where all patients demonstrated improved outcomes.[11] Further research should compare the effects of various needle sizes on clinical scarring versus histological fibrosis in the context of small skin wounds. Additional parameters that have varied across clinical studies which likely also influence treatment outcomes include treatment density, ranging between 5% and 20%, and needle depth, ranging from 2.5 to 5 mm. The optimal microcoring technology design may also depend on the type of skin and specific treatment indication.

Currently, three microcoring devices are commercially available. The Ellacor device (Cytrellis Biosystems, Inc.) features a three-needle cartridge attached to a handpiece and a vacuum system to remove serial skin cores. It is FDA-approved for treating moderate-to-severe rhytids in the mid-to-lower face. The AI.ME device (Venus Concepts Inc., San Jose, CA) uses six rotating robotic needles affixed to a handpiece with a vacuum system and is FDA-approved for aesthetic skin rejuvenation. Finally, the N-Derm device (N-finders, Co., Ltd.) uses a single rotating robotic needle for its microcoring process. Owing to significant differences in designs, the outcomes and specific treatment indications may vary among these devices.

No studies have compared the safety and effects of microcoring with microneedling or fractional ablative laser therapy. Given that microcoring removes skin, its tightening effects are likely more pronounced than those achievable with microneedling.[20] Although both microcoring and fractional ablative therapy remove skin, their outcomes may differ due to the varying physiological effects of mechanical versus thermal energy. The healing profile of microcoring seems to be comparable with microneedling and laser treatments.[12,21,22] Given the more invasive nature of microcoring compared to microneedling, it may be associated with a higher rate and severity of adverse skin reactions. Unlike laser treatments, microcoring does not use thermal energy, potentially reducing the risk of dyspigmentation and scarring, with improved outcomes in darker skin types. Insights on microcoring's safety and efficacy relative to existing techniques will help clarify its role within the landscape of minimally invasive skin rejuvenating treatments.

Conclusion

Microcoring technology is a novel approach to skin rejuvenation. Various designs have been explored, differing in needle size, depth, and treatment density. Current evidence supports its effectiveness in skin tightening and skin quality improvement. Clinically, microcoring has been most used to treat facial rhytids, with additional studies investigating its potential for addressing enlarged pores and acne scars. The procedure seems to be safe and well-tolerated, with mild-to-moderate reported adverse effects. Further research involving larger and more diverse patient cohorts, longer follow-up periods, and comparisons with other skin rejuvenation therapies is needed to confirm treatment outcomes and indications. In addition, deeper insights into the histological and clinical effects of specific microcoring parameters, such as needle size, could enhance our understanding on histological effects and inform device optimization. As the demand for minimally invasive skin rejuvenating treatments rises, more research on innovative approaches and technologies will help clinicians offer patients the most effective treatments.

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Histologic Study of Abdominal Skin Treated With Mechanical Dermal Micro-Coring Technology for Minimally Invasive Skin Removal

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ABSTRACT

Background: Mechanical Dermal Micro-Coring Technology (MCT; Ellacor System) achieves skin tightening and wrinkle reduction through direct mechanical excision of skin cores using hollow needles and collagen stimulation via the wound-healing response.

Aims: To evaluate histopathology and immunohistochemistry of the skin and subcutaneous tissue after a single and multiple treatments with MCT.

Patients/Methods: In this single-center pilot study, 6 female patients scheduled to undergo abdominoplasty were divided into 2 cohorts. Subjects in cohort 1 (safety cohort) received 1 MCT treatment at a depth of 4 mm, 5 mm, and 7 mm, each administered at 1 of 3 unique test areas, with tissue sampling/abdominoplasty 30 days after treatment. Subjects in cohort 2 received 1, 2, or 3 4 mm-depth treatments at 1 of 3 unique test sites, with 30-day intervals for > 1 treatment. Tissue sampling/abdominoplasty occurred 90 days after initial treatment. Histopathology was performed at a central laboratory, and biopsies were evaluated using H&E, Herovici, and Movat stains by blinded evaluators.

Results: A robust increase in new collagen compared to the control tissue was observed for 1 to 3 treatments in all samples. There was no evidence of inflammation or scarring, consistent with earlier preclinical and clinical histology.

Conclusions: MCT-associated histological changes confirm that in addition to skin removal, treatment results in an increase in collagen and homogenization of the dermis in the treated area.

1 | Introduction

Tradition nonsurgical skin tightening methods have relied on either thermocoagulation with energy or mechanical disruption with microneedling to stimulate the wound-healing process and promote the formation of collagen. The effect on skin laxity is indirect with these technologies. Excess skin is not removed; rather, the wound-healing process alone is responsible for the

treatment effect and aesthetic outcomes. This indirect approach has limitations, and oftentimes patients experience suboptimal results, in particular if they have excess skin in combination with volume deficits prior to treatment.

In contrast, Mechanical Dermal Micro-Coring Technology (MCT; Ellacor [Cytrellis Biosystems Inc., Woburn, MA]) [1] utilizes excisional skin remodeling to both remove skin and stimulate the wound-healing response. Skin removal is minimally invasive. Skin cores are excised by hollow needles and evacuated from the needle by suction. Once treatment is complete, an immediate impact is apparent as skin has been mechanically removed. This initial effect is complemented by the wound-healing response, which takes place over time. Patients most often receive between 1 and 3 treatments to achieve the desired effect, with the treatment number contingent upon baseline severity.

Due to the novel mechanism of action for MCT, histologic analyses have been carried out as part of multiple clinical studies, including one that established 500 μm as the safety threshold for coring needle diameter. Full-thickness skin micro-columns at diameters < 500 μm permit treatment without scarring in patients with FST (I-III) [2]. Above this threshold, a subset of patients experience some indication of fibrosis on histology and evidence of persistent redness and some visible removal sites. Based on these findings, the MCT device was developed with 400-μm diameter coring needles. Histologic examination of tissue has not been limited to studies of needle diameter. Overall, the histologic response to MCT has been examined in 29 patients in three separate safety studies and in 59 patients as part of a prospective multicenter clinical trial. No evidence of scarring was observed in these studies with coring needles 400 μm in diameter for up to 90 days in patients with Fitzpatrick skin types I-IV [2–4].

The coring needles, which penetrate the epidermis and dermis, can be used at depths up to 4.0 mm, adjustable in 0.5-mm increments. In clinical practice, multiple treatments are often administered to achieve optimal effects (Figure 1). In this study, we examined histopathology and immunohistochemistry of the skin and subcutaneous tissue following a single treatment and multiple treatments with micro-coring technology at multiple depths.

2 | Methods

In this single-center prospective study, 6 female patients age 18 years or older who were scheduled to undergo abdominoplasty were enrolled. Patients were not excluded based on Fitzpatrick skin type. Patients with a history of abnormal wound healing or keloid formation, as well as patients taking medications or with medical conditions that would worsen bleeding or bruising were not enrolled. Patients were divided into two cohorts. Patients in Cohort 1 (safety cohort) received a single MCT treatment at each of three unique test areas in the abdomen. At each of the three treatment areas, treatment was administered at 1 of 3 depths: 4 mm, 5 mm, and 7 mm for a total of three treatments for each patient in Cohort 1 (Table 1). A non-treated control area was also designated. At 30 days following this single treatment, abdominoplasty was performed. Treated subjects in Cohort 1 were followed for safety assessments at 7, 14, 21, and 30 days post treatment and were monitored for adverse events (AEs).

Patients in Cohort 2 also had 3 unique test areas in the abdomen. At each unique test area, treatment was administered 1, 2, or 3 times at single treatment depth (4 mm), for a total of three treatment areas per patient (Table 1). In instances when multiple treatments were administered, administration occurred at 30-day intervals: treatments were administered on Day 0, Day 30, and Day 60. A non-treated control area was also designated. At 90 days following the initial treatment (30 days following the third treatment), abdominoplasty was performed. Cohorts are summarized in Table 1. Patients in Cohort 2 did not return to the office for follow-up between MCT treatment and abdominolasty; however, patients were encouraged to report any AEs to the treating investigator and were questioned about AEs at the time of abdominoplasty. For both cohorts, an intra-procedural bleeding assessment was conducted based on a 4-point severity scale (none, mild, moderate, severe) for each of the treatment areas.

Histologic evaluations were carried out for all treatment areas to evaluate tissue after treatment and ensure there was no evidence of scarring. Histopathology of the excised abdominal tissue was performed at a central pathology laboratory, and biopsies were evaluated using H&E, Herovici, and Movat stains by

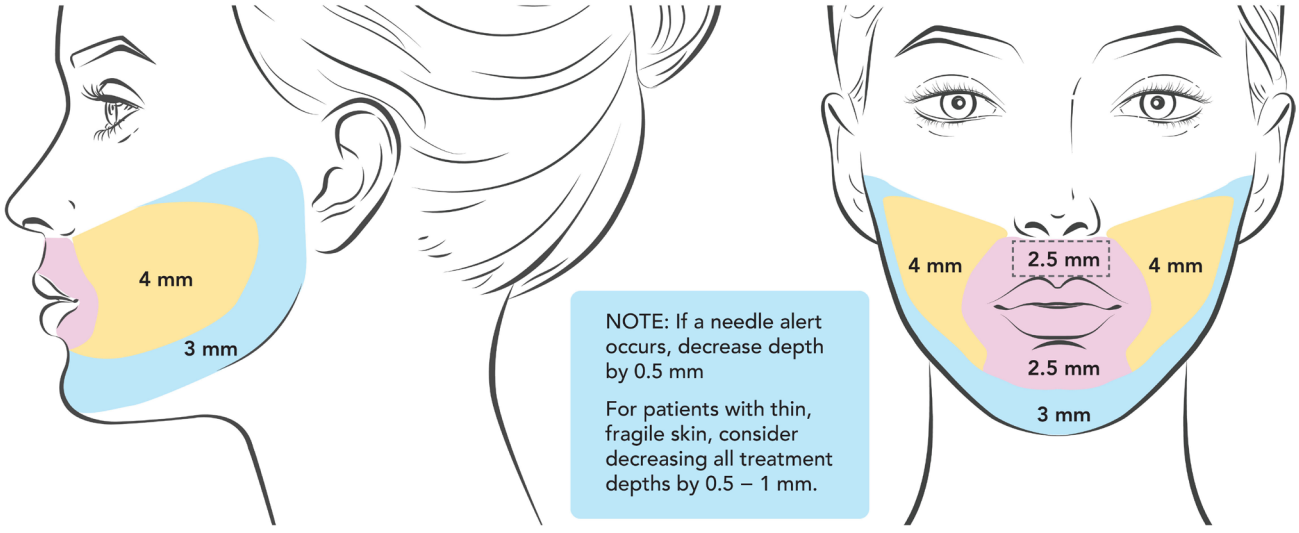

FIGURE 1 | Recommended treatment depths for on-label use of MCT treatment of the face.

blinded evaluators. Increases in collagen noted in the results are based on qualitative observations and are not directly measured. This study was IRB-approved by Allendale IRB, and patients were treated in accordance with the principles outlined in the Declaration of Helsinki.

3 | Results

A total of 6 female patients, median age 37.8 years (range 3–58) were enrolled and completed the study. A total of 4 patients with FST II skin were enrolled, 2 in each cohort; 1 patient with FST III skin was enrolled in Cohort 2; and 1 patient with FST VI was enrolled in Cohort 1. For Cohort 2, all treatment visits for Day 30 (time of second treatment) and Day 60 (time of third treatment) were within 19 to 31 days and 41 to 52 days, respectively. Day 90 visits, when abdominoplasty was carried out, took place between 77 and 89 days post initial treatment. For Cohort 1, all patients underwent abdominoplasty 28 days following initial treatment.

TABLE 1 | Treatment cohorts and assessments.

	Cohort 1	Cohort 2
Treatment	Single treatment Area 1: 4 mm Area 2: 5 mm Area 3: 7 mm	3 treatments, 30 days apart[a] Area 1: 3 treatments Area 2: 2 treatments Area 3: 1 treatment
Assessments	• Safety assessments at 7, 14, 21, and 30 days post-treatment • Tissue sampling for histology taken 30 days post-treatment	• Histology evaluations at 30 days after Area 3 treatment (Day 90)

[a]All treatments were 4 mm depth.

H&E stain demonstrated a healthy, intact epidermis across all 3 treatment areas in both cohorts, with the epidermis in the control area and treated areas appearing intact and healthy. An increase in collagen was observed at all treatment depths compared to control in all subjects without evidence of scar formation (Figure 2). Moreover, Movat staining demonstrated preserved elastic fiber distribution and no histologically visible scar formation at all treatment depths examined (Figure 2C,D,G,H).

Compared to the control areas, the reticular dermis in the treated areas demonstrated changes consistent with reorganization and homogenization of collagen fibers. A robust increase in new collagen deposition was observed for 1 to 3 treatments compared to the untreated control in all subjects (treatments administered ~30 days apart at 4-mm depth; Figure 3). Herovici stain highlighted magenta-staining mature collagen fibers within the reticular dermis and revealed an appreciable increase in new collagen compared to the control tissue in the papillary dermis (Figure 4). In Cohort 1, an approximately 25% to 50% increase in new (immature) collagen fibers was observed within the dermis compared to the control tissue at all treatment depths. An approximately 50% to 100% increase in new (immature) collagen fibers within the dermis was observed in Cohort 2 compared to control for all non-control treatments.

Across cohorts, all treatment-related AEs were typical and expected reactions. Adverse events were restricted to redness and flaking and were mild in severity (Table 2). Mild bleeding was reported for all subjects in both cohorts following treatments. Across both cohorts, all bleeding reported was mild. In Cohort 1, the 3 subjects reported mild bleeding for all treatment depths, and mild bleeding was associated with each treatment in all 3 patients in Cohort 2. No evidence of trauma or significant inflammation was observed in the histologic analysis.

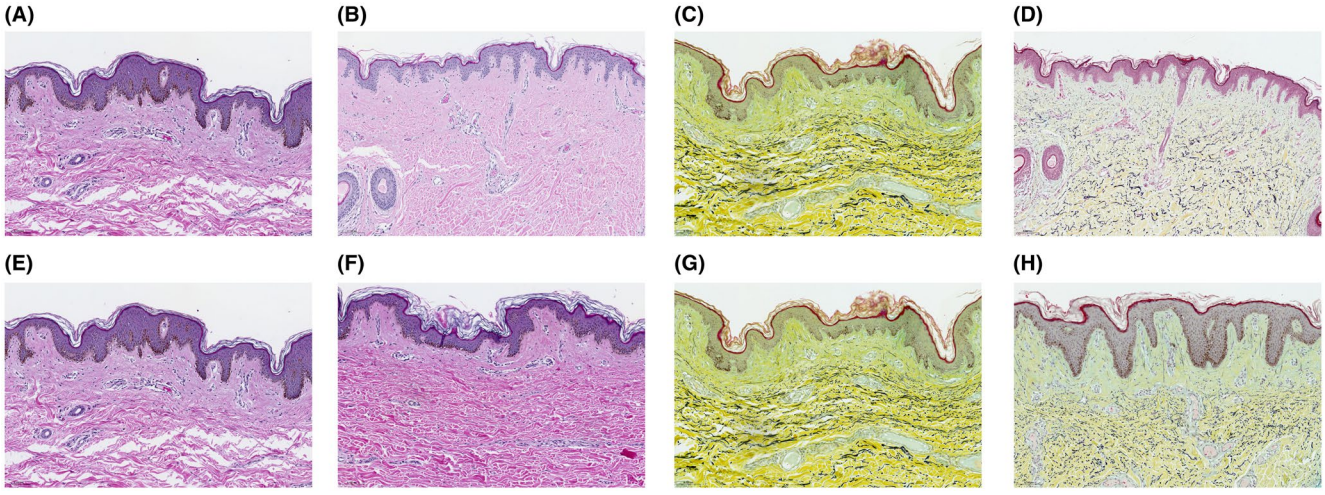

FIGURE 2 | Assessment of multiple treatment depths. H&E (A, B, E, F) and Movat stained (C, D, G, H) specimens from 2 patients in Cohort 1 who received treatments at multiple depths. Samples shown are from the control area (A, C, E, G) and 30 days following treatment at a depth of 7 mm (B, D, F, H). Magnification 30×.

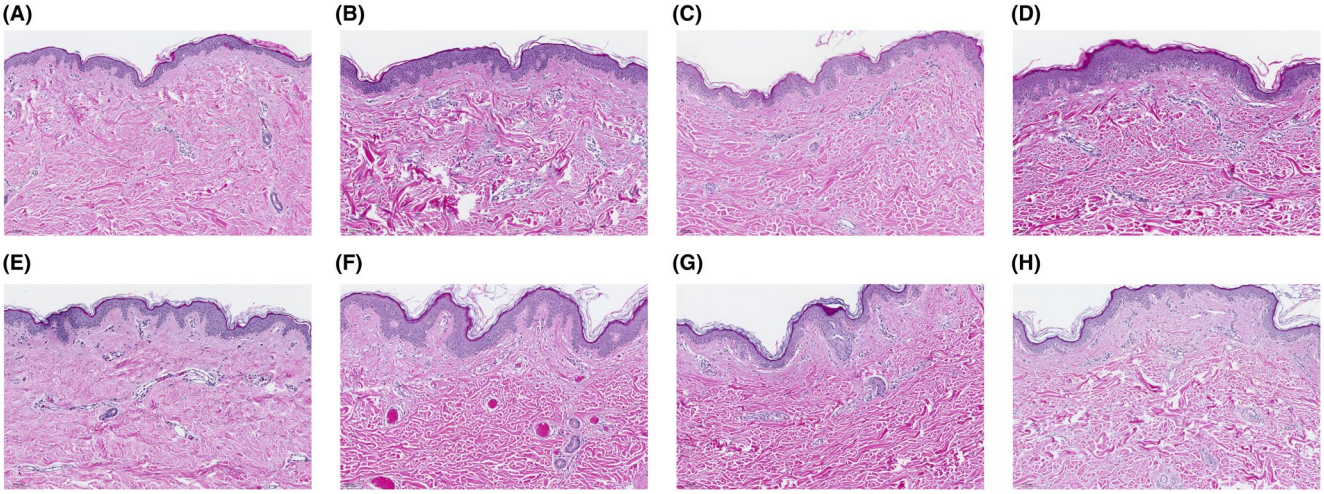

FIGURE 3 | Assessment of multiple treatment sessions. H&E stain from 2 subjects in Cohort 2. Samples are from the control area (A, E) at 90 days following a single treatment (B, F), 60 days following the second of 2 treatments (C, G), and 30 days following 3 treatments (D, H). An increase in collagen was observed at all treatment time points. Magnification 30×.

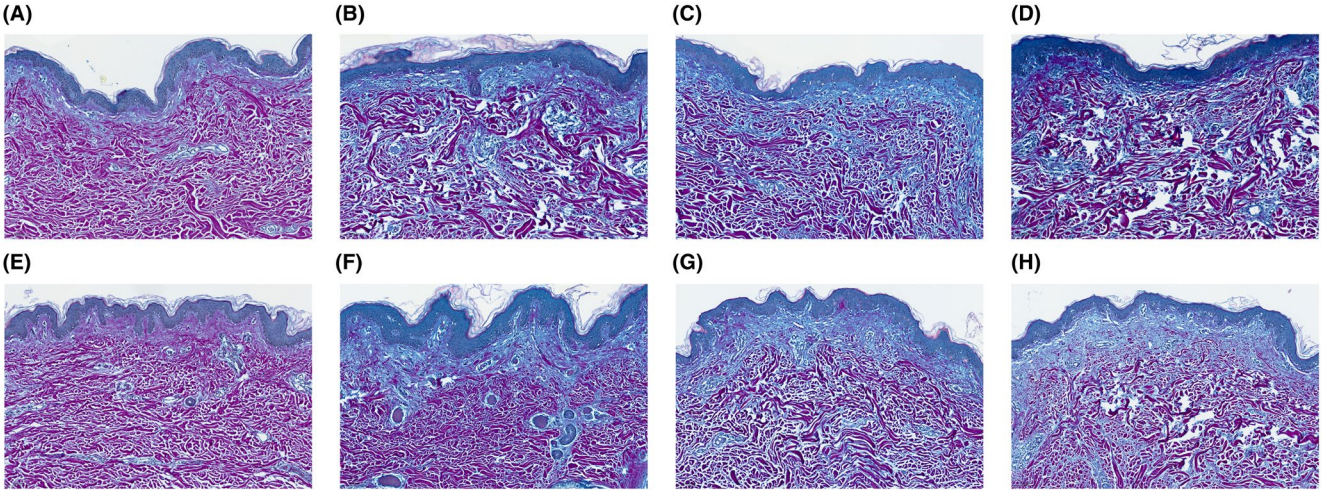

FIGURE 4 | Increase in collagen in the reticular dermis and papillary dermis. Herovici stain from 2 subjects in Cohort 2 who received serial treatments. Samples are from the control area (A, E), 90 days following a single treatment (B, F), 60 days following the second of 2 treatments (C, G), and 30 days following 3 treatments (D, H). Magnification 30×.

4 | Discussion

These findings indicate that MCT results in a substantial increase in collagen and elastin at treatment depths up to 7 mm and with 1 to 3 treatments at a treatment depth of 4 mm with no indication of scarring. This observation of increased collagen without evidence of inflammation is consistent with both safety and clinical efficacy studies, which consistently demonstrate safety at depths up to 4 mm in facial areas [3, 4]. In earlier histology studies, the primary objective was to determine the optimal inner diameter for the coring needles; thus, this is the first study to more systematically address different treatment depths. Clinically, MCT can be applied at multiple treatment depths depending on the area being treated (Figure 1). The finding that minimal evidence of scarring is apparent at depths up to 7 mm may be relevant for future indications outside of the face such as scar treatment, management of fibrotic tissue, or treatment of lax skin on the body, should a deeper depth ever be considered for these purposes.

While this is a preliminary study with a small number of patients, the findings indicate that repeat treatment of the same area is not associated with an increased risk of inflammation or scarring. While this study's population in Cohort 2 is too small to draw any conclusions around the additive benefit of each treatment in terms of collagen induction, a qualitative, incremental increase can be appreciated in Figures 3 and 4 for each treatment. This is consistent with molecular data showing increased expression of COlA1, COL3A1, and elastin at 45 days following a single treatment (at the time of a second treatment) and upregulated further 45 days following a second treatment (90 days following the first treatment) [5]. Clinically, in the authors' experience, most patients require at least two treatments to achieve an optimal effect and sufficient skin removal, and three treatments are generally

TABLE 2 | Adverse Events recorded during the study for Cohort 1 and Cohort 2.

Treatment parameter	Reported AE	Cohort 1 count ($N=3$)
4-mm depth	Flakiness/ flaking skin	2
	Redness	3
5-mm depth	Flakiness/ flaking skin	2
	Redness	3
7-mm depth	Flakiness/ flaking skin	2
	Redness	3
Treatment parameter	**Reported AE***	**Cohort 2 count ($N=3$)**
1 treatment	Flakiness/ flaking skin	0
	Redness	3
2 treatments	Flakiness/ flaking skin	0
	Redness	6
3 treatments	Flakiness/ flaking skin	0
	Redness	9

*No AEs were reported for the control areas.

needed for patients with significant laxity at baseline. These histology data show that on the tissue level, there is no indication that three treatments leads to abnormal tissue effects such as scarring or inflammation. This is important information for clinicians, as it suggests that this number of treatments could be safely applied without increased risk.

Finally, the robust collagen induction observed across all treatment groups is supportive of a dual mechanism for MCT in which skin removal is complemented by a wound-healing response whereby neocollagenesis and neoelastogenesis lead to aesthetic improvement over time following treatment. Further, homogenization of collagen and elastin is seen throughout the dermis as a result of these treatments.

The limitations of this study include the small patient population and the lack of quantitative comparisons between groups. In future studies, quantitative methods in a larger study population could be used to determine the impact of a single versus serial treatments on collagen expression in the skin. Furthermore, this analysis was done on abdominal skin, rather than facial skin, which could partially limit the applicability of results.

5 | Conclusion

The histological changes that occur following MCT treatment in patients undergoing abdominoplasty surgery confirm that in addition to skin removal, treatment results in an increase in collagen in the treated area. Substantial neocollagenesis was observed at treatment depths up to 7 mm and for 1 to 3 treatments, with no evidence of inflammation or scarring.

Author Contributions

D.W., R.W., and R.R. performed the procedures. K.N. is a pathologist and independently processed tissue samples. A.C.B. and K.N. reviewed histology images. J.E. and A.C.B. designed the research study. R.R. assisted in research development and drafting of the manuscript. All authors reviewed and approved the manuscript.

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Conflicts of Interest

Dr. Bhatia is a Consultant and Medical Director for Cytrellis Biosystems Inc.; Jill Edgecombe is a former employee of Cytrellis Biosystems Inc.; Mr. Weir is a consultant for Revance and Cytrellis Biosystems Inc.; Dr. Rohrich has received research support from and served as a consultant for Allergan/AbbVie, the Musculoskeletal Transplant Foundation (MTF), and Galderma; served as a consultant, investigator, and speaker for In Mode; served as a consultant for Evolus; has received research support from Merz, Cytrellis, Rion, and Teoxane; and receives book royalties from Thieme Publishers and instrument royalties from Eriem Surgical (Micrins).

Data Availability Statement

Research data are not shared.

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ORIGINAL ARTICLE
Cosmetic

Cytrellis: A Novel Microcoring Technology for Scarless Skin Removal: Summary of Three Prospective Clinical Trials

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Background: We introduce an innovative and novel technology that achieves scarless skin removal without the use of thermal energy. Microcoring technology (MCT) uses a modified, hollow hypodermic needle to remove skin safely and without a scar. This method is advantageous compared to other fractional devices, given that it has the same benefits as energy-based devices (removal of skin cores without a scar), with the added value of immediate closure along the relaxed skin tension lines, with significantly less thermal energy.

Methods: Three prospective clinical safety trials analyzing MCT treatment on abdominal and facial skin (short- and long-term) are described.

Results: MCT treatment of human skin resulted in scarless skin removal that was well tolerated by patients. Healing occurred rapidly, with limited side effects. Skin area reduction (skin tightening) and increase in skin thickness were observed long term.

Conclusions: MCT treatment of human skin is safe and well tolerated. Although further studies on efficacy are required to evaluate the full potential of MCT in skin rejuvenation, early findings such as skin tightening and increase in skin thickness are encouraging. *(Plast Reconstr Surg Glob Open 2021;9:e3905; doi: 10.1097/GOX.0000000000003905; Published online 29 October 2021.)*

INTRODUCTION

Scarless skin removal has been a major focus of research, with broad clinical application in aesthetic (wrinkle removal, skin tightening, skin rejuvenation, acne) and reconstructive (scar prevention, scar removal, biopsies) surgery, as well as dermatology.[1] Several widely used technologies such as fractional laser, radiofrequency ablation, and microneedling have taken advantage of the ability of the skin to heal and rejuvenate after minor trauma with reasonable safety and efficacy profile.[2–4]

Despite many advantages, energy-based devices such as fractional laser and radiofrequency ablation lead to epidermal and dermal cell necrosis from thermal injury that inhibits immediate wound closure. Histologic analyses have shown that after treatment with fractional laser, the resultant defect fills with microepidermal necrotic debris (MEND) that is remodeled over time.[2] Although fractional lasers and radiofrequency devices demonstrate excellent results in rejuvenation of skin, data on skin tightening is inconclusive.[5,6] We suspect that MENDs prevent early closure of microcores and therefore limit reduction of skin surface area and skin tightening. Further, nonenergy-based devices using microneedles have many benefits, including limited side effects and fast patient recovery.[4] However, without removal of tissue, significant skin tightening is challenging to achieve and has not been proven in the current literature.[7]

Here, we introduce an innovative and novel technology that achieves scarless skin removal without the use of thermal energy. Microcoring technology (MCT) uses a modified, hollow hypodermic needle to remove skin safely and without scar (see Fig. 1). This method is advantageous when compared with other fractional devices, given that it has the same benefits as laser-based devices (removal of skin cores without scar), with the added value of immediate closure along the relaxed skin tension lines (RSTLs), with significantly less thermal energy.

MCT has been evaluated in preclinical animal studies that revealed an excellent safety and efficacy profile.[8,9] Studies performed in porcine skin demonstrated that wound healing in the treatment areas was achieved after

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1 week and erythema was completely resolved at 2 weeks with no evidence of infection or scarring over a 3-month period.[8] At 1 month, a significant increase in epidermal and papillary dermal thickness was seen. Further, collagen content increased by 89% at 3 months.[8] Both skin thickening and increased collagen content indicate histologic endpoints of successful skin rejuvenation. In addition, porcine skin treated at 10% density with a 19 Gauge (G) coring needle exhibited a reduction in skin surface area by 9% when compared with 3% in control areas treated with standard hypodermic needles with no tissue removal ($P < 0.01$). This finding confirms skin tightening after MCT.[9]

Based on these encouraging findings, we conducted three clinical trials to evaluate the safety of MCT treatment in human skin. The primary goal of all studies was to determine safe MCT treatment parameters, evaluate the healing profile of human skin after MCT, and analyze technical device safety. In addition, limited efficacy variables were assessed. The findings of all three trials are summarized in this study.

Takeaways

Question: Is microcoring technology for scarless skin removal safe?

Findings: MCT treatment of human skin results in scarless skin removal that is well tolerated by patients. Healing occurs rapidly with limited side effects. Although further studies on efficacy are required to evaluate the full potential of MCT in skin rejuvenation, early findings such as skin tightening and increase in skin thickness are encouraging.

Meaning: MCT for scarless skin removal is safe and early data suggests skin tightening, as well as increase in skin thickness.

METHODS

All three clinical safety trials were approved by the New England Institutional Review Board as nonsignificant risk medical device studies. All subjects signed informed consent adhering to the guidelines outlined by the International Conference on Harmonization Good Clinical Practice. No subjects were lost to follow-up.

Inclusion criteria for all studies included age over 18, Fitzpatrick skin type I-VI, and ability to provide informed consent. The initial trials were completed in White patients given that the Fitzpatrick skin type is amenable to this new technology. Specific inclusion criteria pertinent to each study are outlined below. Exclusion criteria for all studies included silicone, fat, collagen or synthetic material in the treatment area, skin rash in the treatment area, history of keloid formation, history of hypertrophic scarring, history of bleeding disorder or active use of anticoagulation, history of trauma or surgery to the treatment area, scarring in the treatment area, active/chronic or recurrent infection, active smoking status or history of smoking in the 3 months before treatment, compromised immune system, hypersensitivity to analgesic agents, pregnancy or breast feeding, untreated drug and alcohol abuse, any comorbid condition that could limit ability to participate in the study or to comply with follow-up requirements, and treatment with an investigational device or agent within 30 days of treatment. Additional exclusion criteria for the facial skin trials included evidence of malignancy/actinic keratosis/melasma in the treatment area, history of treatment with dermabrasion in the area in the past 12 months, history of injection with Botulinum Toxin in the past 6 months, excessive sun exposure within 30 days before treatment, and treatment with fish oil in the 14 days before treatment.

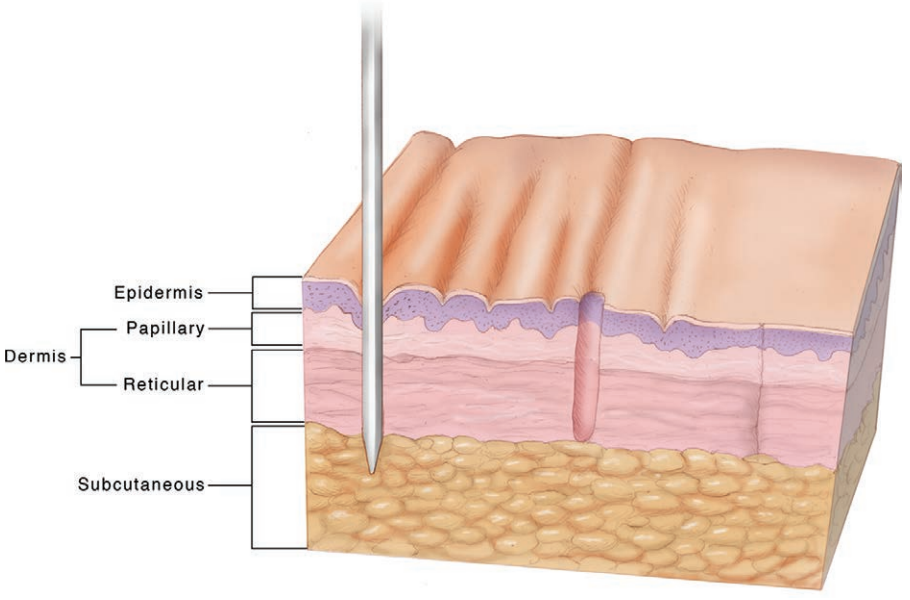

Fig. 1. Illustration of microcoring technology. From left to right, the needle is inserted into the skin, removing a microcore of tissue that heals without scarring.

Subjects received a one-time dose of cefalexin 500 mg before treatment. No antiviral prophylaxis was prescribed, and subjects were not given prophylactic antibiotic or antiviral therapy after treatment. Topical anesthesia with lidocaine/prilocaine cream was provided 30 minutes before the procedures. No dressing was applied to the treated areas. The procedure was performed using a hand-held single needle with one punch. The depth of the needle was manually controllable.

Safety parameters were evaluated for all three clinical trials at all timepoints and consisted of subject reported pain (on a scale of 0–10), bleeding (none, trace, mild, moderate, severe), healing profile (presence of ecchymosis, purpura, fluid accumulation, hyperpigmentation, hypopigmentation, roughness, dryness, inflammation, erythema, crusting on a scale of 0—absent, 1—trace, 2—mild, 3—moderate to 4—severe), scarring (yes/no), and adverse events.

Abdominal Skin Trial

To evaluate MCT for scarless skin removal in human skin, we designed a prospective, randomized controlled in-human feasibility trial that was conducted between October 2013 and October 2014. Five subjects scheduled to undergo abdominoplasty surgery 90 days after enrollment in the study were treated with MCT in the area to be removed during the abdominoplasty operation. The 1 × 1 cm MCT treatment areas and untreated control areas were marked by permanent tattoo before the MCT intervention. Subjects were randomized to MCT needle gauge (G) with diameters ranging from 19 to 24G and treatment density between 10 and 20% of the marked skin surface area.

As an additional safety variable, two subjects underwent tissue biopsy on day 90 to confirm absence of scarring on histology. All safety endpoints were evaluated per treatment area on day 0 and days 1, 7, 30, 60, and 90 post treatment and compared with the untreated control areas.

To determine a possible skin rejuvenation effect, skin thickness was evaluated with DermaLab Combo on day 90 and compared with the untreated control areas.[10] Descriptive statistics and T tests were used for analysis.

Short-term Facial Skin Trial

To determine whether MCT use is safe in the face, a 30 day prospective randomized controlled single-blind clinical trial for use of MCT in the preauricular area was designed and conducted between March 2014 and March 2015. Nine subjects were randomized to MCT treatment in a 2 × 1 cm area of skin in the preauricular area 30 days before excision during facelift surgery. One subject was screened but did not undergo treatment. The MCT treatment area and untreated control areas were marked by permanent tattoo before the intervention. Treatment density was fixed at 10% of the treatment area, whereas needle gauge was randomized to either 22 or 24G.

Based on findings in the abdominal skin trial, erythema and melanin content were evaluated with optical reflectometry as an additional safety variable. All safety endpoints were evaluated per treatment area on day 0 after treatment and days 1, 7, 15, and 30, and compared with the untreated control areas.

Efficacy outcomes included change in skin thickness (DermaLab Combo), and reduction of skin surface area (measured by analysis of the skin surface area between tattooed points via stereo photogrammetry on three-dimensional images obtained with the Canfield Vectra H1 handheld camera). Efficacy endpoints were analyzed at 30 days. Descriptive statistics and paired T tests were performed for analysis.

Long-term Facial Skin Trial

To determine whether MCT treatment is safe long-term, a 90-day prospective single-blind, randomized bilateral paired comparison study in human preauricular facial skin was designed and conducted between October 2015 and October 2016. A total of 15 patients (30 treatment sites) were randomized to MCT treatment in a 2 × 1 cm area of skin in the preauricular area that was not removed surgically. Treatment parameters were randomized to each treatment area, with needle gauge ranging between 22, 24, and 25G and treatment density of either 2.5%, 5%, 7.5%, or 10%.

As an additional safety variable, scarring was evaluated using the Manchester Scar Scale. Safety outcome variables were evaluated at every timepoint. All efficacy endpoints were evaluated at 30 and 90 days.

Efficacy outcome variables were overall aesthetic improvement was measured by subject and investigator reported global aesthetic improvement scale (3 = very much improved; 2 = much improved; 1 = improved; 0 = no change; −1 = worse; −2 = much worse; −3 = very much worse). Study visits were conducted on days 0, 1, 4, 7, 15, 30, 90. Descriptive statistics and paired T tests were performed for analysis.

RESULTS

Demographics

All subjects were White. In the abdominal skin trial, five female subjects with Fitzpatrick skin type 1–3 and a mean age of 46 (±11 years with a minimum age of 34, and maximum age of 58) were included. The short-term facial skin trial included seven female and two male subjects with Fitzpatrick skin type 1–3. Average age was 64.5 (±3.6) with a minimum age of 58 and a maximum age of 71. Eight female and seven male subjects with Fitzpatrick skin type 1–5 were enrolled in the long-term facial skin trial. Mean patient age was 56.2 ± 6 years with a minimum age of 44 and maximum age of 64.

Technical Device Safety

For all studies, the device operated as clinically intended and patterns of microexcisions were generated in abdominal skin, as well as facial skin with needles of 19–24G (abdomen) and 22–25G (face). No device safety events were reported in any of the three clinical trials. See Figure 2 for an example of an MCT treatment area immediately after microcore removal.

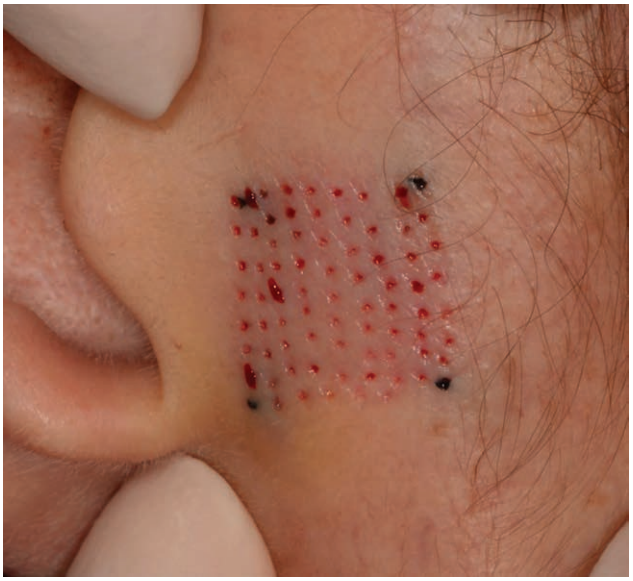

Fig. 2. Immediate result after MCT treatment. Microcores of skin have been removed, resulting in microscopic circular wounds (This picture represents an example of MCT treatment that was performed outside the three clinical trials that are presented in this article. Treatments of facial skin in the short- and long-term facial skin trials were performed in a 2 × 1 cm rectangular treatment area (preauricular), as can be seen in Figure 3).

Clinical Safety Profile

Adverse Events and Serious Adverse Events

In the short-term facial skin trial, one subject developed a superficial wound infection in the preauricular area 21 days after treatment that resolved without intervention. No other adverse events or serious adverse events were reported in any of the three clinical trials.

Pain

Across all treatment areas on abdominal skin, the average pain during treatment was 2.8 ± 1.1 on a scale of 0–10. Pain decreased to 0.4 ± 0.9 on day 1 and 7, and to 0 on all subsequent visits. Average pain in the short-term facial skin trial was 0.4 ± 1 during treatment and 0.4 ± 1.3 on d1, 1 ± 2 on d7 and 0.2 ± 0.7 on day 30. In the long-term facial skin trial, pain during treatment was reduced to 0 ± 0. Mean postprocedure pain was 0.6 ± 0.92 on d1, 0.4 ± 0.8 on d3, 0.07 ± 0.37 on d7, 0.2 ± 0.6 on d15, and 0 ± 0 starting d30 and on all visits thereafter.

Bleeding

Bleeding during treatment of the abdominal skin was trace in two subjects and mild in three subjects. During the short-term facial skin trial, seven subjects experienced mild bleeding during treatment, and two subjects had moderate bleeding. Analysis of the long-term facial skin trial data revealed no bleeding at three (10%), trace at 23 (77%), and moderate at four (13%) treatment sites.

Healing Profile (see Table 1)

MCT-treated skin healed with no scarring (see Fig. 3). During the abdominal skin trial, trace to mild treatment side effects such as ecchymosis, edema, crusting, roughness, dryness, and inflammation were seen up to day 30. Trace to mild redness was present from day 1 to day 90. Trace hyperpigmentation was seen on days 7–90.

The short-term facial skin clinical trial showed trace ecchymosis, crusting, and roughness up to day 15. Trace edema, redness, dryness, inflammation, and hyperpigmentation were present up to day 30.

During the long-term facial skin trial, trace side effects (roughness, dryness, inflammation) were noted up to day 7. Trace redness was seen on days 1–15 and was absent

Table 1. Healing Profile

Abdominal Skin Trial	Ecchymosis	Edema	Crusting	Redness	Roughness	Dryness	Inflammation	Hyperpigmentation	Hypopigmentation
Day 0	0.0	1.1	0.0	0.7	0.0	0.0	0.2	0.0	0.0
1	0.1	0.4	0.0	1.0	0.2	0.0	0.2	0.0	0.0
7	0.1	0.0	0.7	0.9	1.2	0.8	0.2	0.1	0.0
30	0.0	0.0	0.0	2.0	0.5	0.0	0.2	0.8	0.0
60	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.7	0.2
90	0.0	0.0	0.0	0.9	0.0	0.0	0.0	1.1	0.0
Short-term Facial Skin Trial									
Day 0	0.8	1.4	0.0	1.8	0.0	0.0	1.9	0.0	0.0
1	0.6	1.2	0.0	1.9	0.7	0.3	1.6	0.0	0.0
7	0.1	0.1	0.8	1.1	1.0	1.3	0.2	0.0	0.2
15	0.1	0.0	0.2	1.4	0.2	0.7	0.4	0.4	0.0
30	0.0	0.2	0.0	1.3	0.0	0.1	0.3	0.9	0.0
Long-term Facial Skin Trial									
Day 0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.6	0.3	0.3	0.8	0.4	0.1	0.1	0.0	0.0
4	0.6	0.3	0.1	0.8	0.1	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.4	0.1	0.1	0.1	0.0	0.0
15	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Average score [on a scale of 0 (absent), 1 (trace), 2 (mild), 3 (moderate) to 4 (severe)] across all subjects per time point.

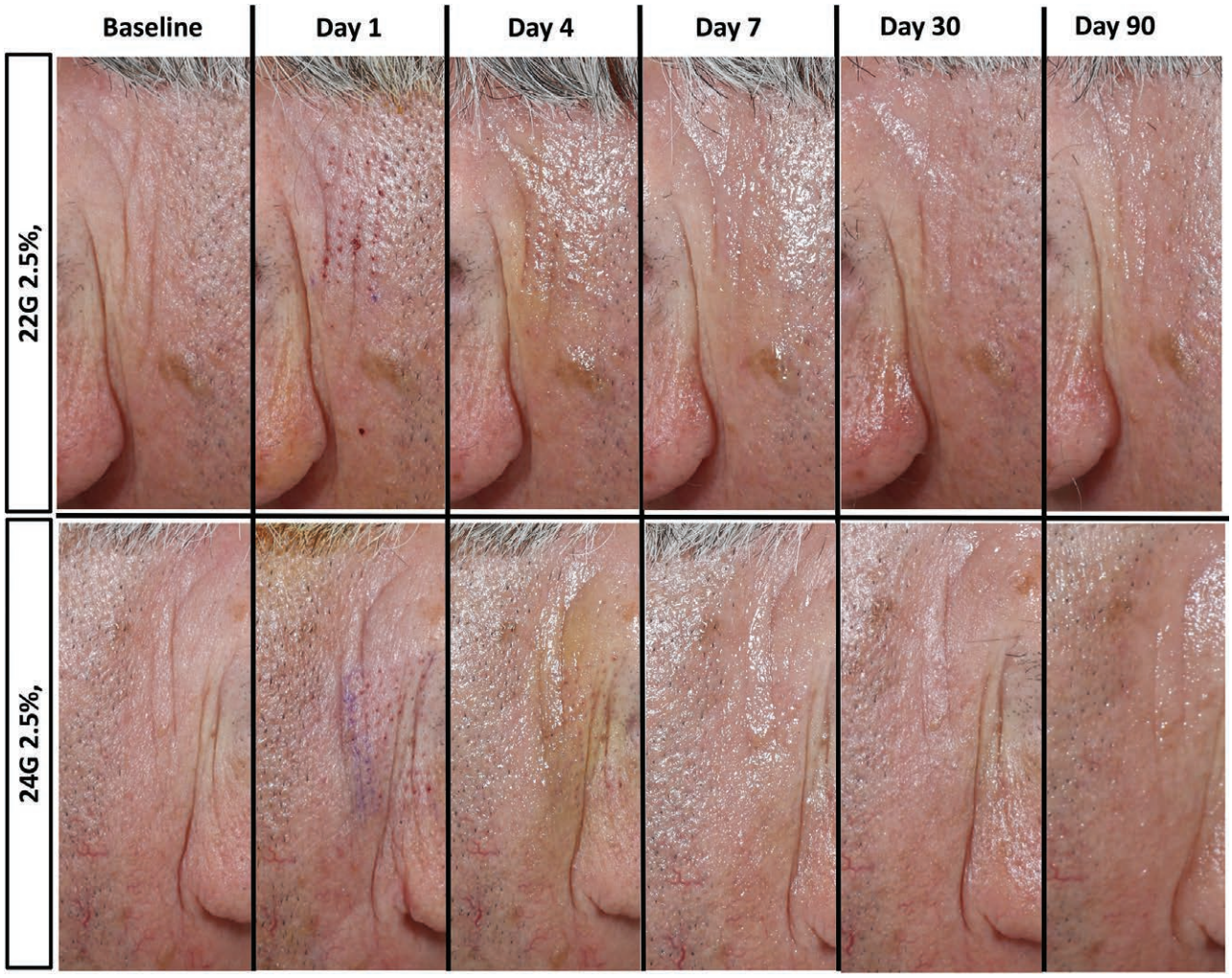

Fig. 3. Wound healing profile after MCT treatment. Most treatment side effects resolved by day 7. Also note clinical improvement in rhytides on day 90.

on day 30 and subsequent visits. Trace hyperpigmentation was seen on day 30 that resolved by day 90.

Additional healing parameters included histologic evaluation of biopsies obtained in two patients during the abdominal skin trial at the day 90 visit that confirmed absence of scarring at 10% treatment density (see Fig. 4). Further, the erythema index that calculated as part of the short-term facial skin trial showed no significant difference between treatment (22.7 ± 7.1) and control (25 ± 6.2) groups on day 30 ($P = 0.16$). In addition, there was no significant difference in melanin index between groups (treatment 40.3 ± 5.7 versus control 43.6 ± 5.3; $P = 0.12$). In the long-term facial skin trial, Manchester Scar Scale evaluation revealed no scar in any treatment area (n = 30) at needle gauge 22–25 and 2.5%–10% treatment density in the preauricular area.

Clinical Efficacy Profile

Skin Thickness

Both abdominal and facial skin thickness increased after MCT treatment (see Table 2). Analysis of the abdominal skin treatment sites revealed a significant increase in skin thickness in treated areas of the abdomen when compared with control areas from baseline to 90 days post treatment ($P < 0.01$). An increase in skin thickness could also be seen for treated facial skin when compared with control ($P < 0.05$).

Skin Surface Area Reduction

In the short-term facial skin trial, skin surface area reduction at 10% treatment density with needle gauge 22 and 24 was on average −9.4% ± 4.3% (−13.9 ± 7 mm^2), which was significant when compared with baseline and control ($P < 0.01$).

Aesthetic Improvement

Analysis of the long-term facial skin trial data revealed that the mean subject global aesthetic improvement scale score was 2.9 ± 0.6 and mean investigator global aesthetic improvement scale was 2.8 ± 0.5 at 90 days (very much improved). There was a visible reduction of rhytids on clinical examination (see Fig. 3).

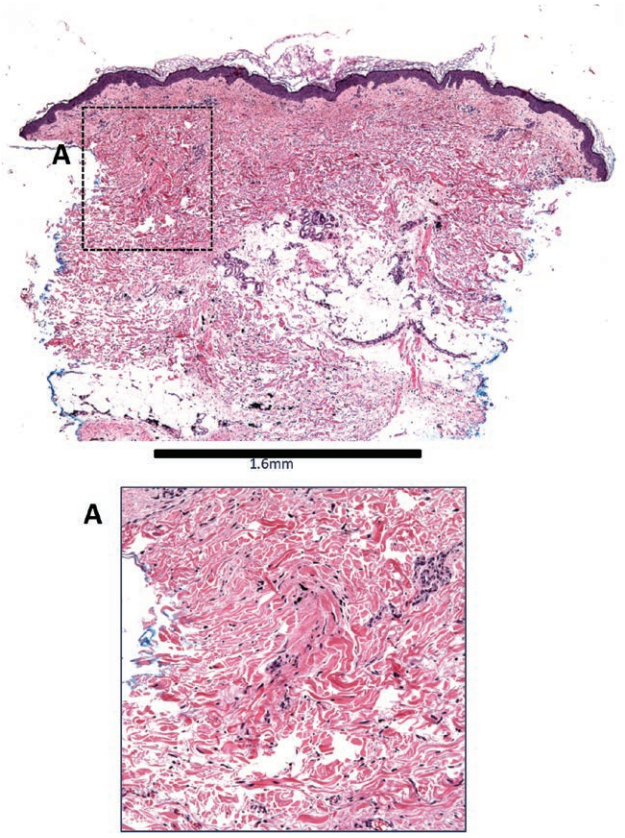

Fig. 4. Histologic analysis. At 90 days after treatment, biopsies show no evidence of scarring in treated areas.

DISCUSSION

MCT uses hollow needles to remove skin without formation of scar tissue. This article summarizes the first experience with MCT treatment in human skin by analyzing the results of three prospective clinical safety trials. We demonstrate that MCT treatment of abdominal and facial skin is well tolerated with minimal pain and bleeding during treatment. It is safe with excellent healing profile and shows signs of skin rejuvenation such as increase in abdominal and facial skin thickness, skin surface area reduction (skin tightening), and global aesthetic improvement.

MCT treatment was well tolerated with only mild pain during and after the procedure. Minimal pain was reported during treatment of the abdomen (2.8 ± 1.1) and facial skin (0 ± 0 to 0.4 ± 1.3). The pain profile improved as coring techniques were refined from the abdominal skin trial to the facial skin trials. A recent review demonstrated that patients undergoing microneedling procedures experienced on average 0.2–3.8 out of 10 pain, which is slightly higher than in our MCT cohort.[11] Therefore, pain levels during MCT treatment are comparable or lower than pain reported with microneedling. In general, microneedling interventions are very well tolerated by patients, and therefore the MCT pain profile appears to be similarly favorable.[12]

Further, transient and self-limited bleeding was observed during treatment that was well tolerated by patients and did not require additional hemostasis. Similar to microneedling, pinpoint bleeding is the endpoint of MCT treatment, and the amount of bleeding that was seen in all three clinical trials (trace to moderate) was within the expected range.

MCT-treated skin demonstrated a favorable healing profile with no signs of clinical or histologic scarring. This finding confirms that scarless skin removal with MCT is possible not only in porcine, but also in human skin. Expected treatment side effects were observed with trace to mild severity across all clinical trials. The side effect profile improved with refined treatment technique. During the final long-term facial skin trial with perfected coring technique, trace side effects such as ecchymosis and edema were present up to day seven with only trace redness persistent until day fifteen and one instance of trace hyperpigmentation on day 30 that resolved by day 90. With fractional CO_2 laser resurfacing, a similar short-term healing profile can be observed with most patients experiencing side effects for around 14 days.[13,14] However, long-term side effects such as hyper- and hypopigmentation seem less common with MCT in this small cohort of patients.[15] Further, the most common severe complications seen with fractional laser treatment such as scarring, herpes simplex virus outbreaks, and acneiform eruptions were not seen in MCT-treated areas although no herpes or antibiotic prophylaxis was subscribed.[16] Future studies in a larger patient cohort are required to further validate these findings.

Table 2. Skin Thickness

	Pretreatment Skin Thickness	SD	Posttreatment Skin Thickness	SD	*P*
Abdominal skin trial					
Treatment areas	1497	268	1642	234	**<0.01**
Control areas	1562	231	1577	178	>0.05
Short-term facial skin trial					
Treatment areas	1856	193	2097	170	**<0.05**
Control areas	1795	160	1914	186	>0.05

Mean skin thickness (in μm) at 10% density measured with DermaLab Combo pre MCT treatment in abdominal skin on posttreatment day 90 and in facial skin on posttreatment day 30.
Bolded values are significant *P* values.

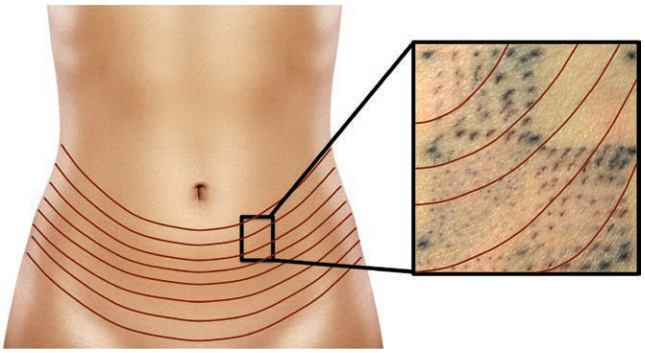

Fig. 5. Closure along the RSTLs. Black pigment was used to mark circular cores that were removed at treatment. After 90 days, the tattoo marks appeared as slits along the RSTL, indicating natural closure along the relaxed tension lines with no visible scarring.

Interestingly, we noted that healing after MCT treatment occurred predominantly along the prevailing RSTLs. After MCT treatment of abdominal skin, the tattooed round cores appeared elliptical along the RTLs at 90 days post treatment (Fig. 5). RSTLs are furrows that are created when the skin is relaxed in the absence of tension. Therefore, surgical incisions are ideally oriented along the RSTLs, as it is well known that wounds heal most inconspicuously under no tension.[17] The observation that MCT cores heal along the RTLSs is very encouraging, as this means ideal and aesthetic wound healing occurs.

Although the primary focus of all three clinical trials was evaluation of safety, notable signs of skin rejuvenation were observed that will be the subject of further studies. Preliminary findings include a significant increase in skin thickness in MCT-treated areas when compared with control in both abdominal and facial skin. One of the main characteristics of aging skin is decreased collagen production, which leads to thinning of the epidermis and dermis.[18] Increase in skin thickness suggests an increase in collagen production and reversal of aging effects.[19]

Further, the average reduction of the facial skin surface area was –9.4% ± 4.3 at 10% treatment density on post procedure day 30, which was significant when compared with baseline and control ($P < 0.01$). During treatment with fractional devices that use thermal energy, MEND fills the treatment area immediately and is remodeled over time.[2] MEND seems to inhibit closure of microwounds. With MCT, closure along the RSTLs occurred within 24 hours without visible interposition of debris. Although these are early results, we hypothesize that absence of MENDS allows for effective reduction in skin surface area and skin tightening.

Finally, both subjects and blinded investigators felt that the overall aesthetic improvement of the MCT treatment areas in the long-term facial skin trial was very much improved, indicating a positive effect overall.

In summary, MCT is an innovative new approach to scarless skin removal that has been shown to be safe for the treatment of abdominal and facial skin. Discomfort during MCT treatment is comparable to microneedling, which is very well tolerated by patients. Further, the healing profile is favorable with only transient trace to mild side effects. Early efficacy results demonstrate promising signs of skin rejuvenation, such as skin tightening and increase in skin thickness after one MCT treatment. We expect increasing efficacy with multiple MCT treatments, which will be the subject of future studies.

CONCLUSIONS

MCT treatment of human skin results in scarless skin removal that is well tolerated by patients. Healing occurs rapidly with limited side effects. Although further studies on MCT efficacy are required to evaluate the full potential of MCT in skin rejuvenation, early findings such as skin tightening and increase in skin thickness are encouraging.

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ORIGINAL ARTICLE
Cosmetic

Dermal Micro-coring for the Treatment of Moderate to Severe Facial Wrinkles

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Background: Micro-coring technology (MCT) removes cores of skin without formation of scars, thereby tightening skin and reducing skin wrinkling. The purpose of this study was to evaluate the safety and efficacy of MCT with the dermal micro-coring device for the treatment of facial wrinkles.

Methods: This prospective, multicenter clinical trial included fifty-one subjects who underwent MCT treatments of the mid to lower face. The primary study endpoint was change in the Lemperle Wrinkle Severity Scale. Secondary study endpoints were change in Global Aesthetic Improvement Scale (GAIS), participant satisfaction, and evaluation of treatment outcome by an independent review panel. All study endpoints were evaluated at 1, 7, 30, 60, and 150 or 180 days after treatment. Procedure bleeding, pain, and early healing profile were also captured.

Results: The mean Lemperle Wrinkle Severity Scale change was 1.3 grades. Improvement in the GAIS was reported for 89.7% (87/97) of treated sites, and average improvement of GAIS was 1.5. Participants reported satisfaction with 85.6% of treatment sites. The independent review panel correctly identified 84.2% of the post-treatment photographs as post-treatment. Procedure bleeding and pain was mild with good healing responses and patient-reported average down time of 3 days.

Conclusions: The results of this study demonstrate the safety and efficacy of MCT with the dermal micro-coring device for the treatment of moderate to severe facial wrinkles. MCT led to significant improvement of facial wrinkles with high patient satisfaction and fast recovery time and should be considered in patients who are seeking minimally invasive treatment for wrinkles of the face. *(Plast Reconstr Surg Glob Open 2022;10:e4547; doi: 10.1097/GOX.0000000000004547; Published online 17 October 2022.)*

INTRODUCTION

Aging skin is characterized by skin laxity and the appearance of fine lines and wrinkles. Numerous invasive and noninvasive techniques for skin surface area reduction (skin tightening) have been described in the literature. Minimally invasive, nonsurgical treatments such as microneedling, ablative and nonablative lasers, radiofrequency, and micro-focused ultrasound have been successfully used to treat mild skin redundancy.[1–4] However, moderate-to-severe skin redundancy and wrinkling is difficult to improve with minimally invasive techniques. On the other end of the spectrum, facelift surgery provides the most pronounced cosmetic outcomes in reduction of wrinkles and skin laxity.[5] However, a facelift does not fully address all areas of facial skin laxity (periorbital and perioral region, nasolabial fold, marionette lines), and is associated with prolonged recovery and the presence of scarring.

Micro-coring technology (MCT) is an innovative technology that combines the benefits of minimally invasive treatment (fast recovery) with the advantage of scarless skin removal, thereby enabling treatment of moderate to severe skin laxity and wrinkles. The dermal micro-coring device (DMCD) uses hollow coring needles that, when inserted in the skin, excise cores in the size of the

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needle's inner diameter. Compared with micro-needling that only punctures the skin without removing any tissue, the DMCD needle removes full-thickness cores of skin with diameters in the range of 400 microns. Removal of human skin cores occurs without the formation of a scar (see Figure 1).[6]

Based on several preclinical and clinical trials, the DMCD offers a safe and effective treatment for facial wrinkles in the intended patient population. Early safety studies in porcine skin demonstrated favorable wound healing in all treatment areas after 1 week with no evidence of infection or scarring over a three-month period.[6] Further, at 1 month, a significant increase in epidermal and papillary dermal thickness, as well as increased collagen content was seen.[6]

In addition, three prospective clinical safety trials analyzed MCT treatment on abdominal and facial skin (short and long-term).[7] All trials showed that MCT treatment was well tolerated by participants, with only mild pain and transient, self-limited bleeding during and after the procedure. MCT-treated skin further demonstrated a favorable healing profile with no signs of clinical or histologic scarring. Although the primary focus of all three clinical trials was evaluation of safety, notable signs of skin rejuvenation were observed. Preliminary findings included a significant increase in skin thickness in MCT-treated areas when compared with control in both abdominal and facial skin. Further, the average reduction of the facial skin surface area was 9.4% ± 4.3 at 10% treatment density, which was statistically significant when compared with baseline and control ($P < 0.01$).

Takeaways

Question: Is MCT safe and effective for treatment of facial wrinkles?

Findings: The mean wrinkle grade change was 1.3 grades. Participants reported satisfaction with 85.6% (83/97) of treatment sites. Procedure bleeding and pain was mild with good healing responses and a patient-reported average down time of 3 days.

Meaning: MCT is safe and effective in treatment of moderate-to-severe facial wrinkles of the mid to lower face, and should be considered in patients who are seeking minimally invasive treatment for wrinkles of the face.

Based on the encouraging findings seen in animal and human studies, the aim of this prospective, multicenter clinical trial was to demonstrate the safety and efficacy of the DMCD for the treatment of moderate-to-severe facial wrinkles in the mid to lower face.

METHODS

This prospective, multicenter clinical trial was approved by the New England Institutional Review Board. All subjects signed informed consent adhering to the guidelines outlined by ISO 14155, 21 US Code of Federal Regulations Parts 50, 54, 56, and 812 (as applicable); US Health Insurance Portability and Accountability Act of 1997 (HIPAA); and International Conference on Harmonization E6 Good Clinical Practice.

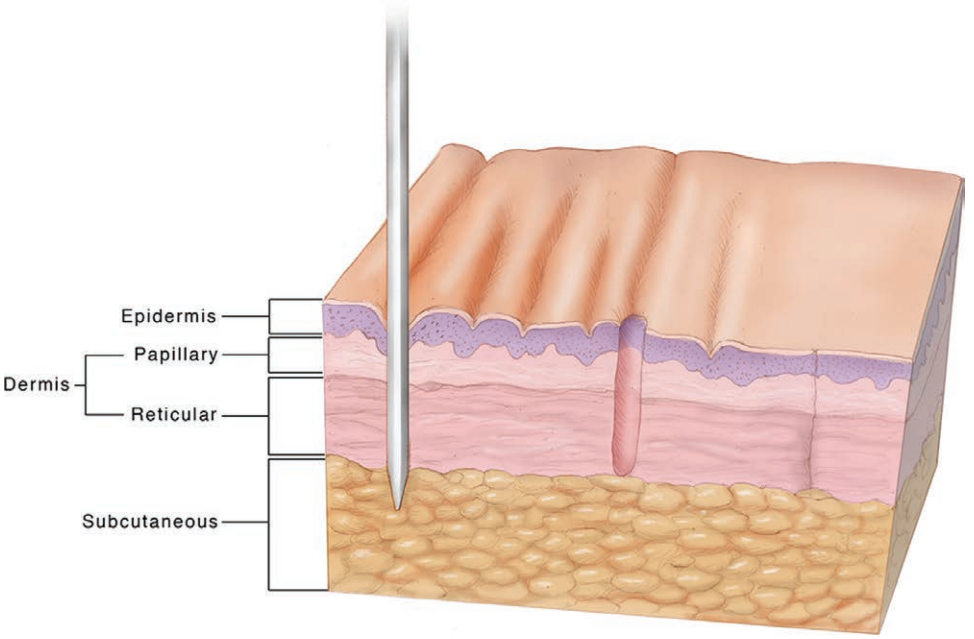

Fig. 1. Illustration of micro-coring technology. From left to right, the needle is inserted into the skin, removing a micro-core of tissue that heals without scarring. Reprinted with permission from *Plast Reconstr Surg Glob Open*. 2021;9:e3905.[7] This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

Investigational Device Description

The DMCD is composed of a reusable nonsterile hand piece that can be wrapped in a sterile drape. Sterile consumable components consist of a single or triple needle array with tubing and a patient-contact vacuum spacer flange. The hand piece is connected to the system console, which provides power distribution, vacuum control, and the user interface. The device is controlled from the touchscreen graphical user interface. The user interface allows the operator to select a single or three-needle array, the percentage of desired tissue removal (up to 8.5%), and the depth of penetration into the skin (up to 5mm). Only the triple-needle cartridge was used during this study.

The operator moves the device over the treatment area and actuates the system using a foot pedal to engage the vacuum spacer flange and begin treatment actuation. Once the hand piece positioning drive system moves the needles into position, the needles penetrate the skin. The needles are then retracted from the skin, removing a core of tissue from the skin. The tissue is then aspirated by the vacuum pump via the needle-hub tubing into a vacuum-tube system and is collected in an external (disposable) filter. The positioning system and needle continue to move through a predefined pattern to treat an area within a $1 \times 1\,cm^2$ square. The system is then moved by the user to the next treatment area. The cycle is repeated until the intended treatment is delivered. The suction system removes the cores from the back end of the needles. The cores build up along the suction path (ie, in the cartridge, tubing, filter, etc). Although there is no feedback from the device, cores are visible in the tubing path. The minimum micro-core count per treatment was 6000 in this study. The maximum number of cores that can be removed by the triple-needle cartridge is 24,000. Therefore, the coring device is still sharp after 6000 uses. The frequency of the puncture rate is up to 12Hz. The 8.5% skin removal pattern takes approximately 2 seconds using the triple-needle cartridge. The maximum needle velocity is 2 m per second. Treatments typically took between 15 and 30 minutes for the area studied.

The commercial device is indicated for use by medical professionals for the treatment of moderate and severe wrinkles in the mid and lower face in adults aged 22 years and older with Fitzpatrick skin types I–IV.

Study Design

Subjects who presented to four investigational sites were enrolled in this study (Laser and Skin Surgery Center of New York, Miami Dermatology & Laser Institute, Practice of Brian S. Biesman, M.D., and Laser & Skin Surgery Center of Northern California). The first subject was enrolled on September 10, 2019 and the last subject was enrolled on October 25, 2019. The last follow-up visit was completed on June 26, 2020.

Subject Enrollment

Fifty-nine subjects were screened and enrolled in the study. A total of 59 subjects underwent at least one treatment. A total of 53 subjects underwent two treatments, and a total of 49 patients underwent three treatments. A total of five participants (8.5%) discontinued the study or were lost to follow-up before the 90-day follow-up period after the final treatment. Despite the difficulties associated with the COVID-19 pandemic, the overall follow-up visit compliance was excellent at 96.1% (571 actual/594 expected visits). Final follow-up visits after the final treatment were completed for 54 of the 59 treated participants (91.5%). Only subjects who completed at least two treatments were included in the final analysis (n = 51).

Inclusion Criteria

Inclusion criteria included men and women between 40 and 70 years of age at baseline with mid to lower face wrinkles with a grade of 3 (moderately deep wrinkles) and/or 4 (deep wrinkles, well- defined edges) on at least one side using the Lemperle Wrinkle Severity Scale (LWSS) and Fitzpatrick Skin Type I to IV, who were able and willing to provide written informed consent and comply with all study-related procedures and follow-up visits.

Exclusion Criteria

Exclusion criteria included lesions suspicious for any malignancy or the presence of actinic keratosis, melasma, vitiligo, cutaneous papules/nodules, or active inflammatory lesions in the areas to be treated; history of keloid formation or hypertrophic scarring; history of trauma or surgery in the treatment areas in the past 6 months; scar present in the areas to be treated; silicone injections in the areas to be treated, injections of dermal or epidermal fillers in the areas to be treated; fat or botulinum toxin in the areas to be treated, or any other facial procedure within the study treatment areas, within the past 6 months (ie, dermabrasion, laser, radiofrequency, chemical and mechanical peels); active smoking status or having quit within 3 months before treatment; active, chronic, or recurrent infection; history of compromised immune system or currently being treated with immunosuppressive agents; history of sensitivity or allergy to any topical, injectable, or other preparation used during the study, such as Aquaphor, topical or injected anesthetics (ie, lidocaine, benzocaine, procaine, chlorhexidine, povidone-iodine, or epinephrine); excessive sun exposure, use of tanning beds, or tanning creams within 30 days before treatment and for the duration of the study; treatment with aspirin or other blood thinning agents within 14 days before treatment; history or presence of any clinically significant bleeding disorder; treatment with an investigational device or agent within 30 days before treatment or during the study period; currently pregnant or breastfeeding; or planning to become pregnant during the study period.

Study Visits

Participants underwent study-required visits at baseline, treatment (up to three treatments), and at 1, 7, 30, 60, and 90 days after every treatment. Treatments took place 1 month apart. Due to the COVID-19 pandemic, some visits could not be completed at the expected time. Amendments were incorporated to allow follow-up visits at 120, 150, or 180 days as the final follow-up.

Study Endpoints

The primary endpoint of the study was the Lemperle Wrinkle Severity Scale (LWSS) responder rate.[8] A responder was defined as a participant with a reduction of one grade or more on the LWSS at the final follow-up visit as determined by the investigator. Further, an independent expert panel consisting of three reviewers (two plastic surgeons and one dermatologist) evaluated baseline and post-treatment photographs and determined LWSS grade (0 = no wrinkles, 1 = just perceptible wrinkles, 2 = shallow wrinkles, 3 = moderately deep wrinkles, 4 = deep wrinkles, well-defined edges, 5 = very deep wrinkles, redundant fold).

The secondary endpoints of the study were patient satisfaction (0 = extremely dissatisfied, 1 = somewhat dissatisfied, 2 = slightly dissatisfied, 3 = neither satisfied nor dissatisfied, 4 = slightly satisfied, 5 = somewhat satisfied, 6 = extremely satisfied) and global aesthetic improvement as assessed by the investigator comparing baseline and post-treatment photographs on the Global Aesthetic Improvement Scale (GAIS) (3= very much improved; optimal cosmetic result, 2 = much improved; marked improvement in appearance from the initial condition, but not completely optimal, 1 = improved; obvious improvement in appearance from the initial condition, 0 = no change; the appearance is essentially the same as baseline, –1 = worse; the appearance is worse than the original condition, –2 = much worse; marked worsening in appearance from the initial condition, –3= very much worse; obvious worsening in appearance from the initial condition).

Treatment endpoints were bleeding severity during treatment as assessed by the investigator (mild, moderate, severe), patient-reported pain score (0–10), and healing response (absent, trace, mild, moderate, severe for the following categories: delayed bleeding, hematoma, redness, burning, hyperpigmentation, scarring, crusting, hypopigmentation, skin necrosis, dryness/roughness, infection, skin peeling, ecchymosis, inflammation, tenderness, edema, itching, tightness/pulling, erythema, pain/discomfort, tingling).

Micro-coring Treatment

Micro-coring treatments were performed with the DMCD using 22-gauge needles and densities of 6.5%, 6.7%, 7.9%, and/or 8.5% (percent of skin removed per 1 cm^2). (**See Video [online],** which displays the micro-coring treatment. The DMCD uses hollow coring needles that, when inserted in the skin, excise cores in the size of the needle inner diameter.) Coring depths were between 3 and 5 mm. The minimum core count was 6,000 micro-cores per treatment. Treatment location was the mid to lower face (see Fig. 2). Upon completion of the treatment, the area was rinsed with sterile saline, and Aquaphor was applied. Aquaphor was applied daily for a minimum of 7 days with no other dressing. No antibiotics were administered. Injectable local anesthetic was administered before the procedure based on standard office procedures and at the discretion of the physician. Typically, patients were injected with approximately 20 to 40 cc of a lidocaine and epinephrine solution. Occasionally, other forms of analgesia were used in addition to the injected local anesthesia, such as nitrous oxide (Pronox), topical anesthesia (administered for 30 minutes before the local anesthesia injections), or Tylenol.

Statistical Analysis

Subjects who completed at least two treatments were included in the final analysis (n = 51). SAS Institute Inc. version 9.4 was used for analysis. The change in the LWSS was analyzed using repeated measures analysis of variance modeling methods. The model contained a random effect for subjects and an effect for side (left/right). The mean change from baseline for the LWSS was 1.3 grade [95% CI: 1.22, 1.42]. The lower limit of the 95% confidence interval for the mean change was greater than 1.0 grade, indicating that these data support the primary endpoint conclusion of 1 grade or greater mean improvement, assuming independent observations. The primary hypothesis assumption was that the mean difference from baseline would be 0.78 with a 95% CI of 0.15; this value was exceeded with an observed mean difference of 1.3 [95% CI: 1.22, 1.42] and the endpoint was met. A repeated measures analysis of variance (RMANOVA) was also performed with a repeated factor in the model for side (left/right) and reviewer.[1–3] (**See table, Supplemental Digital Content 1,** which displays the results of the RMANOVA. **http://links.lww.com/PRSGO/C165**.)

Fig. 2. Treatment area. The treatment location for this study was the mid to lower face. © 2022 Mica Duran. Used with permission.

RESULTS

Demographics

The study population consisted of predominantly white, non-Hispanic women over 60 years old with type II or III Fitzpatrick skin types and LWSS scores of 3 or 4 at baseline (Table 1).

Wrinkle Reduction

The mean change from baseline for the LWSS was 1.3 grade [95% CI: 1.22, 1.42]. (**See figure, Supplemental Digital Content 2,** which displays representative results. **http://links.lww.com/PRSGO/C166**.) The independent reviewer panel correctly identified 84.2% (245/291) of the 90-day post-treatment photographs as post-treatment. Improvement in the GAIS was reported for 89.7% (87/97) of treated sides. The mean change in GAIS demonstrated an average improved score of 1.5 at the last follow-up compared with baseline (Fig. 3).

Patient Satisfaction

When considering all treatment sides, the overall satisfaction rate (including slightly, somewhat, and extremely satisfied) was 85.6% (83/97) (Figure 4).

Treatment Endpoints

Procedure bleeding was mild in most cases (≥78%). There were no reports of severe bleeding. Procedure pain was mild (see Table 2). Most (90%) participants had absent, trace, or mild healing responses by 7 days after treatment (see Figure 5). Moderate ecchymosis, edema, erythema, hyperpigmentation, itching, pain/discomfort, redness, tenderness, and tightness were seen in less than 10% of cases at 7 days. A limited number (<5%) of participants reported moderate dryness, ecchymosis, erythema, hyperpigmentation, and redness at 30 days after treatment. No skin reactions were reported at 90 days after treatment. The mean reported down time was three days.

Table 1. Baseline Demographic Information

Demographic Variables	Mean ± SD or % (n/N)
Gender (women)	98.0% (50/51)
Age (y)	62.9±5.92
Height (inch.)	64.1±2.54
Weight (pounds)	145.8±27.56
Ethnicity (non-Hispanic)	96.1% (49/51)
Race (White)	(51/51)
Fitzpatrick skin type (FPST) I	9.8% (5/51)
FPST II	68.6% (35/51)
FPST III	15.7% (8/51)
FPST IV	5.9% (3/51)
Lemperle score (right side)*	
1	2.0% (1/51)
2	5.9% (3/51)
3	58.8% (30/51)
4	33.3% (17/51)
Lemperle score (left side)*	
1	0.0% (0/51)
2	2.0% (1/51)
3	60.8% (31/51)
4	37.3% (19/51)

Results are presented as mean ± SD or % (n/N).
*Participants were required to have a Lemperle score of 3 or higher on at least one side.

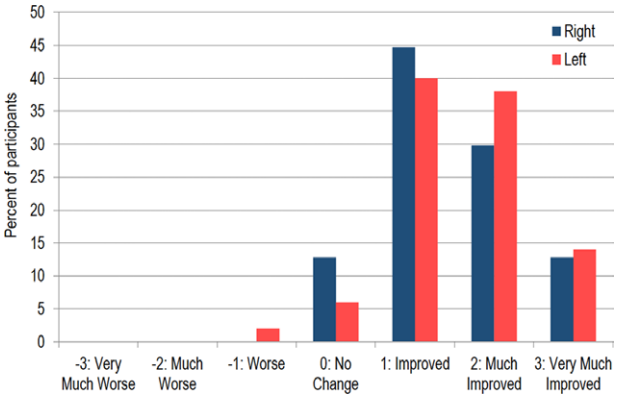

Fig. 3. GAIS change from baseline to final follow-up by side. Improvement in the GAIS was reported for 89.7% (87/97) of treated sides. The mean change in GAIS indicates an improved score of 1.5 at the last follow-up compared with the baseline.

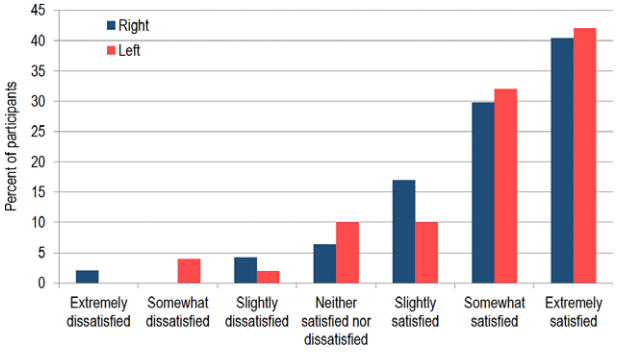

Fig. 4. Participant satisfaction by side. When considering all treatment sides, the overall satisfaction rate (including somewhat, slightly, and extremely satisfied) was 85.6% (83/97).

Table 2. Procedure Pain

Side	Pain Score		
	Treatment 1	Treatment 2	Treatment 3
Left	1.5±1.98 (50)	2.0±1.77 (50)	2.8±2.21 (46)
Right	1.3±1.76 (47)	1.9±1.57 (47)	2.7±1.99 (43)

The mean pain experienced during treatment indicates minimal discomfort for all treatments. Results are presented as mean ± SD (number of treated areas).

Adverse Events

No serious adverse events were reported. A total of nine adverse events were reported in five participants. Five of the adverse events were not related to the device or treatment. Four of the adverse events in four participants were considered adverse device effects (ADEs). The ADEs were black eye, cheek numbness, redness, and prolonged needle marks on cheek. The ADEs were mild to moderate in severity and did not require any intervention. All adverse events were resolved by the end of the study.

DISCUSSION

MCT is an innovative, minimally invasive treatment method that enables removal of skin without formation of

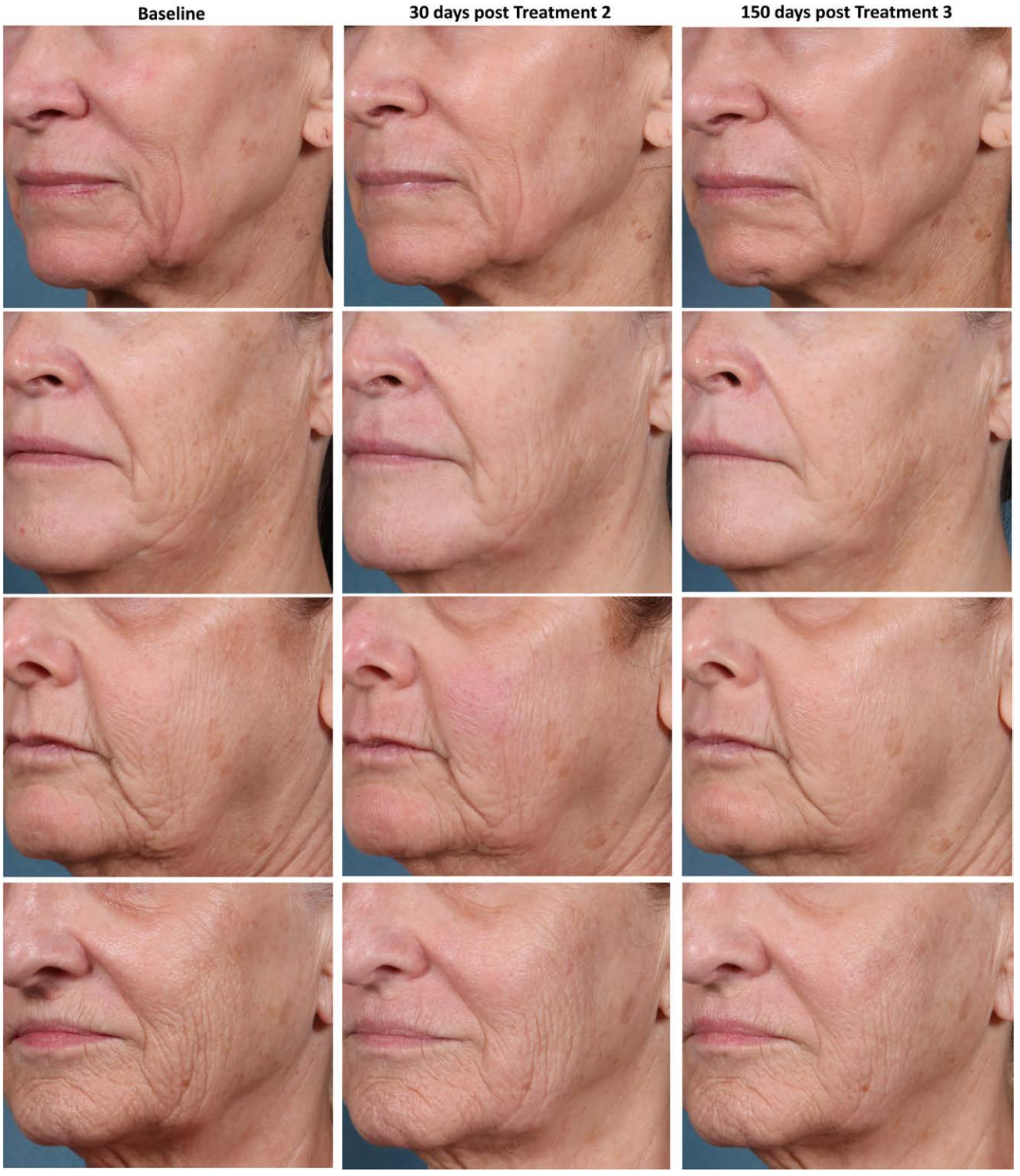

Fig. 5. Healing profile. Most (90%) participants had absent, trace, or mild healing responses by 7 days after treatment.

scar, thereby effectively removing redundant skin and skin wrinkles. This study analyzed DMCD for the treatment of moderate to severe wrinkles of the face. We demonstrate that MCT treatment of facial skin is well tolerated with minimal pain and bleeding during treatment, as well as short recovery time and good healing profile. Further, DMCD leads to significant improvement of moderate to severe facial wrinkles with high patient satisfaction.

Moderate to severe skin wrinkles of the lower face in the perioral region including the nasolabial fold and marionette lines are difficult to treat with currently available minimally invasive techniques or facelift surgery. There is a

need for novel devices to treat skin redundancy in this area effectively. The current study showed that treatment with DMCD improved mid to lower face wrinkles with a mean change of 1.3 on the LWSS at 90 days after treatment. (**See figure, Supplemental Digital Content 2, http://links.lww.com/PRSGO/C166**.) In comparison, a single-center, open label study of 48 subjects undergoing four sessions of micro-needling 30 days apart showed a mean change in wrinkle severity of 0.4 for nasolabial folds and 0.3 for marionette lines according to the LWSS at 90 days after treatment.[9] Therefore, the DMCD may provide a greater efficacy in the reduction of wrinkles in these key areas. The change in the LWSS for the DCMD was further reflected by the improvements seen in overall aesthetic appearance of the lower face on the GAIS in the vast majority (89.7%) of treated sides. Participants were satisfied with the treatment outcome in most cases (85.6%). Therefore, DMCD appears to be three times as effective as micro-needling in reduction of wrinkles. This change in the LWSS was further reflected by the improvements seen in overall aesthetic appearance of the lower face on the GAIS in the vast majority (89.7%) of treated sides. Participants were satisfied with the treatment outcome in most cases (85.6%).

As demonstrated in prior safety studies, the procedure was very well tolerated with local anesthesia. Bleeding was mild in most cases and the mean procedure pain scores were between 1.2–2.8 (on a scale of 0–10). In comparison, subjects undergoing micro-needling treatment of the face have been shown to experience a mean pain score of 5.3 out of 10 (range 3.8–6.1) during treatment.[9] A comparison of pain scores is difficult, given that micro-needling treatment typically does not require local anesthesia when compared with micro-coring treatment.

Comparable to prior clinical trials, the MCT healing profile was favorable with most patients experiencing full recovery after treatment at 7 days (≥78%).[6] The most common skin reactions (erythema, edema, ecchymosis, redness, itching, tightness) described by the investigators were comparable to those seen after micro-needling procedures.[10] In addition, although the MCT skin reactions were comparable to those seen with fractional CO2 laser treatments, less common but significant complications that have been reported after laser treatment such as bacterial and viral infections and scarring were not observed with the DCMD.[11,12] The reported skin reactions were trace to mild, and no moderate or severe skin responses to treatment were observed. Given the mild nature of skin changes seen after MCT treatment, application of makeup starting 48–72h after treatment can mask skin changes. The skin recovery time from MCT appears to be slightly longer than for micro-needling procedures, and significantly shorter than for fractional CO_2 laser resurfacing, after which most patients experience side effects for around 14 days.[11,13] However, participants after MCT treatment were able to return to their normal activities of living almost immediately with little down time (three days on average).

No long-term skin reactions were observed at the last follow-up visit, including hypopigmentation or hyperpigmentation. This is an advantage over laser-based treatments that are associated with postinflammatory hyperpigmentation, as well as hypopigmentation.[12] Although the underlying pathomechanism of pigmentation disorders remains unknown, it is possible that energy-based devices such as lasers increase the risk of pigment disturbances as compared to non-energy-based devices such as DMCD.

Around 15% of patients did not experience the expected results, which also correlates with the 15% of patients; the independent review panel was not able to identify a difference between pre- and post-treatment pictures. Other minimally invasive rejuvenation techniques have reported similar patient satisfaction rates.[14] One possible confounding factor that has been reported in the literature are high patient expectations pre-procedure that lead to lower satisfaction rates with other devices such as micro-needling.[15] However, for any type of procedure, we would not expect all patients to be satisfied.

There are several limitations to this study. First, the study population consisted predominantly of white, non-Hispanic women over 60 years old with type II or III Fitzpatrick skin type. Further studies will be required to demonstrate safety and efficacy in subjects with Fitzpatrick skin type IV and higher, as well as in different gender, age groups and ethnicities. In addition, there was no control area that was left untreated. However, standardized photography allowed for comparison to baseline.

CONCLUSIONS

The results of this micro-coring technology study demonstrate the safety and efficacy of the DMCD for the reduction of moderate to severe facial wrinkles in the intended patient population. DMCD led to significant improvement of facial wrinkles in the mid to lower face with high patient satisfaction and fast recovery time and should be considered in patients who are seeking minimally invasive treatment for wrinkles of the face.

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