Evaluation of the wound healing response post - deep dermal heating by fractional RF: INTRACEL

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Background and Objectives: A new device, INTRACEL heating up deep dermis using microneedle of bipolar and monopolar RF in a minimally invasive way; Fractional Radiofrequency Microneedling ("FRM") technology was introduced lately. This study was conducted to see the process of the wounded dermis being healed after FRM procedure for both human and porcine skin.

Study Design and Methods: A maximum power of 700W RF can be used on bipolar mode to deliver the thermal energy directly into the dermis. 49 micro needles are diffused to 1cm^2 area on its tip, and those needles are insulated except its end edge of 300㎛ to avoid the thermal damage on the skin surface when it penetrates into skin. 10 healthy patients and aseptically processed a slice of pork meat were involved in this clinical trial. Healing responses were observed by the time after the treating procedure at various energy levels. Biopsy was conducted to see the wound healing process immediately after the treatment, 2days, 14days, 28days, and 70days post the treatment.

H&E stain and HSP47 stain were conducted to see the changes in inflammatory cell, collagen. Also, the study has conducted RT-PCR with the tissue biopsied from Micro-pig covering 10 weeks to see mRNA change of collagen, HSPs, and matrix metalloproteinase (MMPs).

Results: No thermal damage was observed on the epidermis and upper dermis except the area the micro needle electrodes passed, but the collagen was damaged within the reticular dermis.

Denaturalized collagen column was seen through H&E test. 10 weeks later, the observation clearly showed that the pattern of new collagen was granulated on the area of damaged collagen. Volumn increases were observed in 70 days from the FRM treatment in various inflammatory cytokine, HSPs, procollagen 1, procollagen 3, tropoelastin, and fibrillin through RT-PCR test. Seeing the change due to the energy level used for the treatment, the tissue treated with high level energy showed increase of the number of fibroblast, and activate the collagen reproduction as well as the replacement of damaged collagen.

Conclusion: FRM leaves minimal wound by its needle penetration on epidermis and upper dermis, and fractional deep dermal heating is possible in the lower dermis. Such damaged collagen is healed by new collagen being granulated as time passes, and increases fibroblasts. These conditions are well observed in RT-PCR results, as HSPs and HSP expressions supporting the production of a new collagen in the tissue stained with HSP antibody. FRM treatment is expected to be good for a tightening, wrinkle reduction, and scar treatment, as it uses various needle depths with the different targets to induce the production of a new collagen and elastin.

Key words: bipolar; fractional; micro-needle electrodes; neocollagenesis; neoelastogenesis; deep dermal heating; Jeisys; wound healing.

INTRODUCTION

When ASR (Ablative Skin Resurfacing) was introduced to the aesthetic market, it was effective but it produced patients a lot of pain with a long down time. In contrast, NAR (Non-ablative Rejuvenation)'s side effects and pain was a lot less than ASR, but it provided insufficient efficacy to reach the patient's satisfactory level. Later, fractional laser technology was introduced, but epidermis was burnt and left pigmentation when it tried to deliver the strong energy to deep skin layer. It was obvious as it uses epidermis as the passage of the thermal energy. The new bipolar micro-needle RF device was invented to satisfy such demands and needs. This machine has microneedles and it delivers Fractional RF energy to induce the thermal damage in the target area of the dermis. Fractional radiofrequency microneedles (FRM^{TM}) makes thermally and

partially injured columns in deep dermis. The dermis in between the thermally injured columns is not wounded. A histology, immunohistochemistry, and molecular biological studies are adopted to observe wound healing process on human body and micro-pig. As results, we found out the fact that FRM operation induces a strong wound healing response to collagen draw out and elastin remodeling by revealing Heat Shock Protein (HSPs) and cytokines

STUDY DESIGN AND METHOD

A study was carried out total of 70 days with 10 subjects. Patients and micro-pig were treated and observed immediately after, 2 days, 14 days, 28 days, and 10 weeks later. The observation had done prior to their prescheduled biopsy to capture the temporal evolution of the in vivo wound healing response.

FRM delivers bipolar RF into dermis by 49 micro-needle electrodes of 1.5mm or 0.8mm in their length. Micro needles are inserted into skin at 90 degrees. RF is emitted to dermis for 0.2 seconds after the insertion. The delivery times of RF energy are different by the energy level, and the lengths of needles could be chosen among 0.5, 0.8, 1.5, and 2.0mm.

Histological wound healing response was measured to determine deep dermal heating of collagen, elastin, and inflammation. Incision treatments were done for 2 different 2mm biopsies at each time points. The biopsies was set in 10% neutral buffered formalin and moved into paraffin. 10 paraffin or sections were stained with H&E and HSP47 through serial section. Semi-quantitative RT-PCR is used to measure the changes in molecules of remodeling within the dermis after RF treatment. Electrophoresis was implemented after observing 2.5mm punch biopsy followed by RT-PCR. The densitometry analysis using AlphasEase software was used, and ß-actin, ß-globin glyceraldehyde-3-phosphate dehydrogenase was used as housekeeping genes. Amplicon intensity ratio was estimated by dividing the intensity of housekeeping gene with the intensity value for the gene of interest by the intensity value of for ß-actin. The study observed wound healing response in the human body and micro-pig by histology, immunohistochemistry, molecular biology technologies. Research findings indicate that FRM technology enables coagulation necrosis formed column to be developed in the dermis, and induced dramatic wound healing response,

remarkable increase in HSP along with dynamical remodeling of collagen and elastin. Thus, this deep dermal fractional heating, FRM technology will be good for facial wrinkles, tightening and scar treatment.

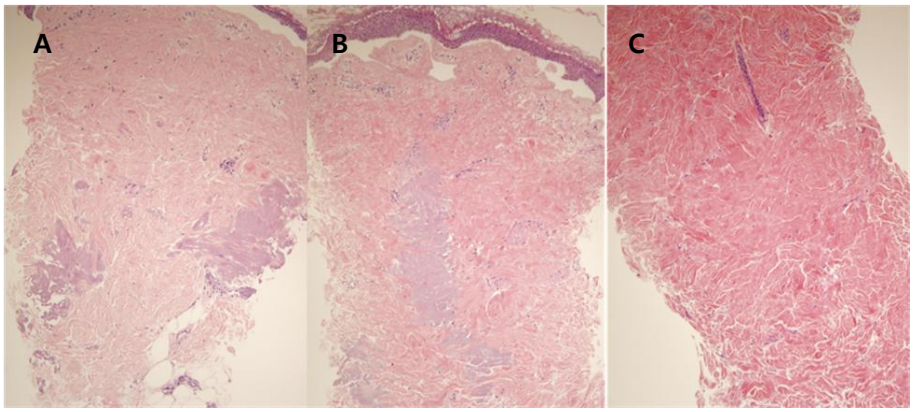


Fig.1. FRM lesions post-treatment.

Study adopted in vivo test on human skin immediately, 14 days, 10 weeks post FRM treatment. Observation indicates remodeling in the dermis for long 10 weeks. Immediate postoperative shown as “(A)”, “(B)” is postoperative 14days, and “(C)” is postoperative 10weeks. The figure of immediate postoperative shows a clear approval of deep dermal fractional heating without damage on the epidermis, and the density of collagen postoperative 10 weeks more increased than immediate postoperative. Every approval shows dermis remodeling and the progress of new collagen was being created. All images are H&E stained and shown at 2X the original magnification.

RESULTS AND CONCLUSION

Deep dermal fractional heating

To see the change in the tissue after FRM treatment, biopsied tissue was stained by H&E immediate, 2days, 14days, 28 days, and 10 weeks post-treatments. Thermally damaged area was detected in reticular dermis immediately after FRM treatment (Fig.1A). Coagulation part is formed in the deep dermis. Collagen denatured area is disappearing gradually 14 days post-treatment (Fig.1B), and then replaced with a new collagen completely in 70 days post-treatment

(Fig.1C). A connection of two coagulation columns with needles tracts on the epidermis were observed in the serially sectioned tissue in the cell just after the treatment (Fig.2)

Collagen damages are repaired as time passes

Penetration of inflammatory cells was seen to the time points. From postoperative 2 days post treatment slight permeation of inflammatory cells is seen (Fig.3A), partially damaged collagen is absorbed in 14 days and new collagen is seen (Fig.3B). Postoperative 28days, the increase in young fibroblast is observed (Fig.3C). Lesion is being replaced with new collagen in 70 days. HSP47 is revealed in the dermis between 28 days and 70days after the operation unitedly with the response of inflammatory cells (Fig.4)

Various RT-PCR has been taken before the treatment and in the various time points to understand better on the results of molecule events arousing by FRM operation.

Research found that Cytokine, revelation increase for 4 weeks stably but MMPs increased gradually. HSP47 increased over 3 times until 70 days and the revelation level of extracellular matrix protein also continued to increase up to 5, 3 times before operation in tropoelastin and procollagen cases (Table.1)

Neo-collagenesis is correlated to a degree of damage.

This research shows the relationship between a new collagen production and energy level on damage, as the observation shows the increase of the fibroblast and HSP47 at the various energy levels.

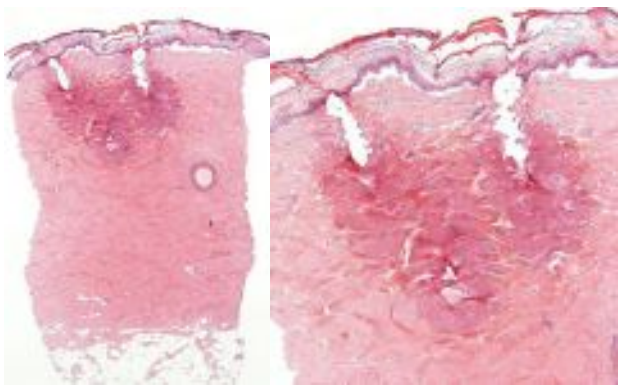


Fig.2. Immediate after FRM treatment.

Coagulation columns were made that connected by the two electrodes of bipolar RF plus and minus being connected precisely

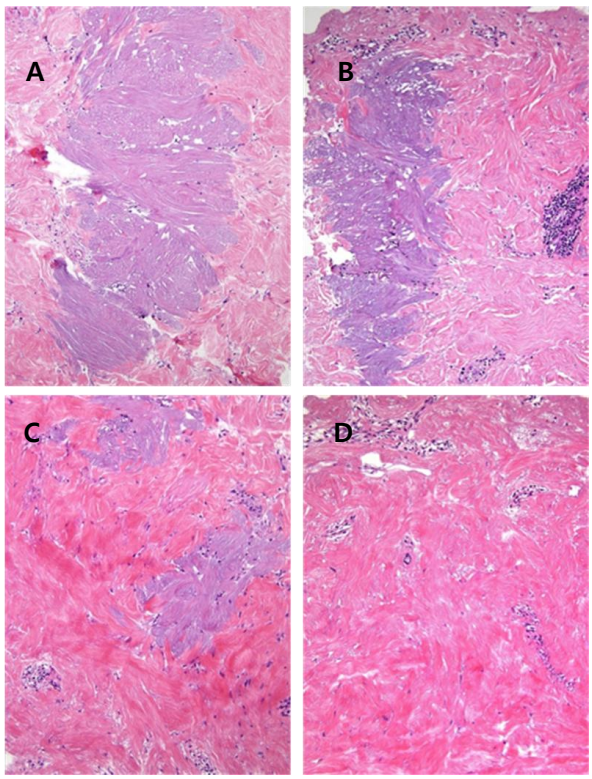


Fig.3. the amorphous degeneration

This is more prominent and there is a minimal inflammation in the lesion in 2 days post-treatment (A). Mild infiltrate of chronic inflammatory cells are present in the lesion and adjacent perivascular spaces 14 days post treatment. The lesion got absorbed and appeared edematous. The irregular collagen tissue partially replaced to the degenerated lesion In 28 days post treatment(C). The lesion is almost replaced by collagen and was remarkably raised cell density in 70days post treatment (D). The image is seen at the 4X original magnification. As the energy level increased, collagen production also increased along with the number of fibroblast (Fig.5). HSP47 also revealed more in the higher level (Fig.6). Biopsy showed that the number of the fibroblast didn't increase in the low energy level, and only the hypertrophic response which can get fibers thicker. The number of cells increases during the wound healing, the effect continued a long time, in general.

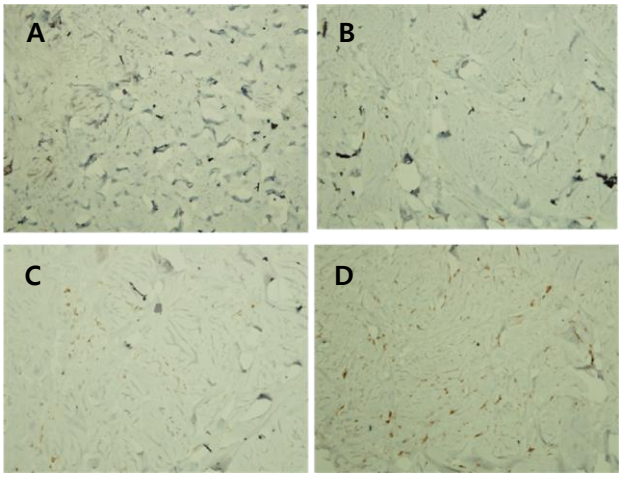


Fig.4. HSP47 responses to FRM treatment.

The tissue of micro-pig was stained with anti-human HSP47 post FRM treatment. (A) is immediately post treatment, (B) is 14 days post treatment, a minimum of HP47 expression was detected in the dermis immediately post FRM treatment. HSP47 increases gradually (B), revealed between 28 days(C) and 10 weeks (D), and diffused causing the coagulation column to be well recovered.

No changes beyond the treatment depths.

HSP47 revelation area was observed to see the influence on the extension of collagen remodeling which can be caused by FRM operation. The comparison of H&E expression and HSP47 shows the occurrences of the strongest revelation at the area of collagen denaturation. However, it didn't reveal any energy level in the deeper area (Fig.7). Therefore, it is better to try FRM to treat the target area when the lesion is in the deep area.

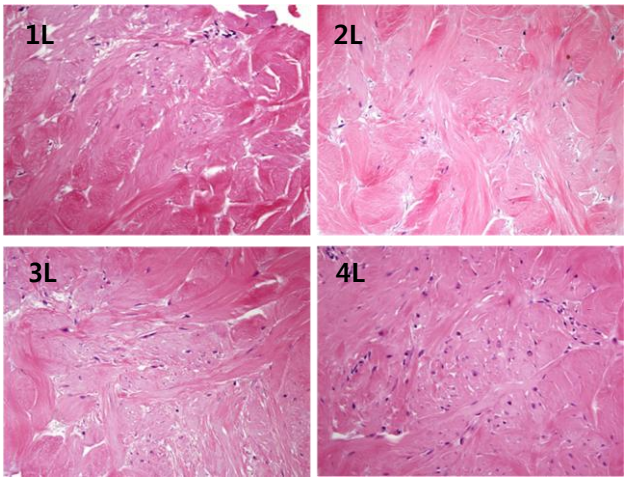


Fig.5. Fig of micro-pig tissue 70 days post FRM treatment. Nucleus and fibers are increased more as energy level get higher

Fig.6. HSP47 response 70 days post FRM treatment. In fact, it is doubled in the higher energy level, which means high energy level causes the greater collagen composition.

Discussion

The 10 weeks observation post FRM treatment has shown dermis remodeling process such as increased production of HSP47 and procollagen, and a full replacement of turning denaturalized collagen into a new collagen. The study proved the actual volume effect by showing increased production of procollagen and elastin in the immunohistochemistry (ICC) and RT-PCR. The result of FRM treatment is better when it operated with a high energy level as it produced more collagen in the study. FRM treatment can be proceeded with no side effect and short downtime.

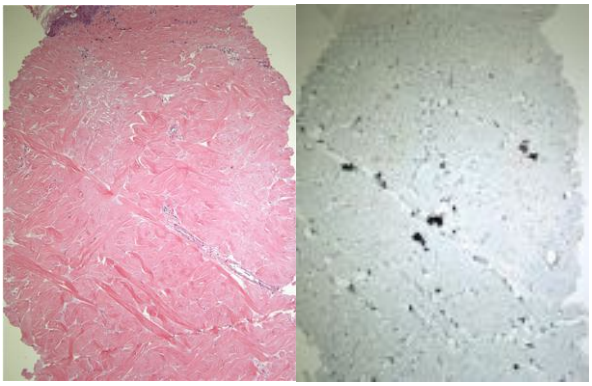


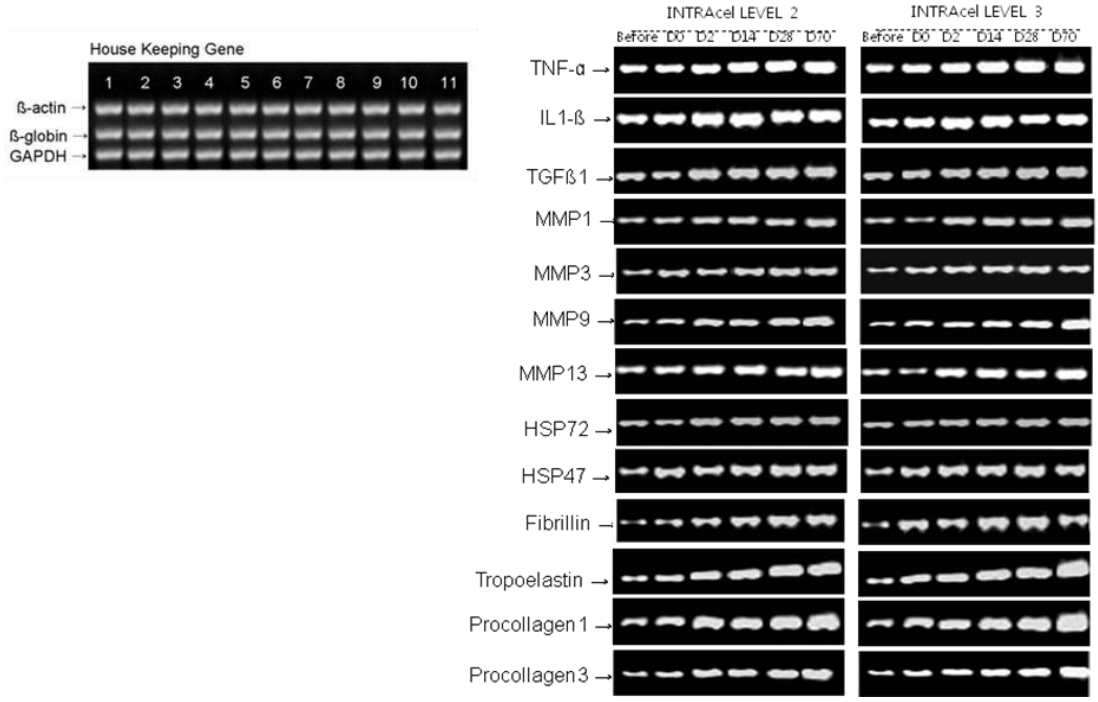
Fig.7. Responses of HSP47 to FRM treatment.

HSP47 is revealed between denatured areas, but never revealed in the deep dermis deeper than the area treated before.

TABLE 1. Response to FRM Treatment of Various Wound Healing Genes Involved in Dermal Remodeling

	Baseline	1.5 3L D0	1.5 3L D2	1.5 3L D14	1.5 3L D28	1.5 3L D70
TNF-α	0.32	0.38	0.4	0.4	0.45	0.58
IL-1ß	0.26	0.33	0.35	0.35	0.4	0.42
TGF-ß1	0.39	0.38	0.42	0.42	0.46	0.58
MMP-1	0.26	0.42	0.36	0.36	0.38	0.37
MMP-3	0.31	0.22	0.39	0.39	0.35	0.46
MMP-9	0.43	0.49	0.87	0.87	1.01	1.13
MMP-13	0.41	0.46	0.67	0.67	0.89	0.81
HSP72	0.62	0.78	0.52	0.52	1.65	1.62
HSP47	0.51	0.62	1.15	1.15	1.42	1.81
Fibrillin	0.84	0.98	1.21	1.21	1.20	1.54
Tropoelastin	0.27	0.36	0.82	0.82	1.12	1.36
Procollagen1	0.67	1.08	1.18	1.18	2.07	2.67
Procollagen 3	0.74	0.92	1.02	1.02	1.32	1.62

Relative expression was calculated as the ratio of the expression level of the gene of interest/expression level of b-actin at each particular time point.



Through the study, fractional deep dermal heating system on a selected target area is expected to provide good and positive efficacy for a skin tightening, wrinkle reduction, scars and pore treatment.