ELECTROPHOTOBIOMODULATION IN THE TREATMENT OF FACIAL POST-BURN HYPERTROPHIC SCARS IN PEDIATRIC PATIENTS

SUMMARY. Hypertrophic scar continues to be one of the leading reasons for surgical and non-surgical treatments after burn healing. Facial post-burn hypertrophic scars can cause severe functional and emotional disability, as they are usually difficult to conceal. Numerous nonsurgical and surgical therapies have been used for the treatment of hypertrophic scars. This study describes the combination of bipolar radiofrequency, intense pulsed light and cooling (given the collective term ‘E-light’), and reports the outcomes of its use in the treatment of post-burn facial hypertrophic scars in a series of sixty-five patients in the pediatric age group. There were no reports in the literature of the use of this modality (E-light) in the treatment of facial post-burn hypertrophic scars in pediatric patients. Results showed that the mean decrease in total VSS score for all patients was 5.8. Regarding the satisfaction of the parents of our patients, 66.15% rated the result excellent, 24.61% rated it good and 9.23% rated it fair. We received no poor ratings for the final result, with a significant reduction in total Vancouver scar scale after treatment (P-value = 0.000). The E-light therapy technique studied in this work is effective, safe and economical if compared to other treatment modalities that can be used in the management of facial post-burn hypertrophic scars.

Keywords: electrophotobiomodulation, hypertrophic scars, facial scars, electric light energy specific action (ELESA), intense pulsed light (IPL), radiofrequency (RF)

Introduction

Hypertrophic scarring continues to be one of the main indications for surgical and non-surgical treatments after burn healing.1

Post-burn facial hypertrophic scars can cause severe emotional disability, as they are usually difficult to conceal. Burn scars can also cause physical disabilities. A contracture of a hypertrophic scar can cause a decrease in range of motion. The loss of skin adnexa (e.g. sebaceous glands) leads to skin dryness and itching. As the epidermal cover of the scar is fragile, epidermis can break down easily, especially if scratched. Due to all the above factors, these scars represent a great challenge for plastic surgeons.2,3

Cellular and molecular events associated with hypertrophic scars include persistently high levels of transforming growth factor-β (TGF-β) and connective tissue growth factor (CTGF). Also, there is an increase in the number and activity of fibroblasts causing abnormal accumulation of extracellular matrix. As the pathogenesis of hypertrophic scars, in general, is still poorly understood, their treatment is still difficult.4

Numerous nonsurgical and surgical therapies have been used for the treatment of hypertrophic scars, including silicone sheets and gel, compression therapy, ultrasound, tissue expan-
sion, excision, intrallesional injections (steroids, chemotherapeutic drugs and interferon), radiation therapy, cryotherapy and photothermolysis. There are reports on the efficacy of pulsed dye laser 595nm in the treatment of keloids and hypertrophic scars.

Both radiofrequency (RF) and intense pulsed light (IPL) are known treatments for facial rejuvenation, hair removal, scars and rosacea. Radiofrequency and intense pulsed light have been used separately and combined. Bipolar RF current flows to areas with the least resistance. When Bipolar RF and IPL are combined, IPL energy primes the tissues by preheating the tissues of the treated area and thus, directs the RF field specifically to that area. To achieve this selectivity, the RF pulse duration must be set longer than that of the intense pulsed light (since both of them start simultaneously) to preheat the target tissue and thus increase RF selectivity. This RF selectivity will distribute the generated heat mainly to the target area with minimal damage to surrounding tissue. This selectivity also helps to reduce the amount of energy needed, which is especially beneficial in patients with darker skin colour as they are less tolerant of these treatment modalities.

The senior author of this article used the term E-light to describe the combination of RF, IPL and cooling. The senior author reported that the combination of RF, IPL and cooling is successful in treating unpleasant scars.

There are no other reports in the literature on the use of E-light in the treatment of facial post-burn hypertrophic scars in pediatric patients. This work is the first to report the outcome of E-light treatment on facial post-burn hypertrophic scars in pediatric patients.

Materials and methods

Ethical commitments

All the procedures performed in this research work that involved human participants, as well as the design of this study, were approved by the Ethical Research Regulations Committee of our university, which follows the National Research Ethics Committee of the National Supreme Council of Universities. The National Research Ethics Committee regulations are compliant with the 1964 Helsinki declaration and its later amendments on ethical standards. The legal guardians of all the participants in this study signed informed consent, which included the use of their medical data and clinical photography in scientific publications.

Patients

Sixty-five patients with facial post-burn hypertrophic scars were enrolled in this study. Patients selected for the study belonged to the pediatric age group and had to have been treated in our university hospital burn casualty unit. They had to be cooperative and compliant. They also had to be free from skin diseases, immunity disorders and photosensitivity. The patients should not have received any other treatment for their facial scars before the start of our treatment protocol. The authors started E-light treatment sessions once they detected hypertrophic scars while the patients were still in our inpatient service or during following up in our university hospital’s outpatient clinic.

A plastic surgeon helped as an independent assessor of the scar score before and four weeks after the end of treatment by E-light. Assessments were carried out according to the Vancouver scar scale scoring system (VSS). To assess the satisfaction of the patient’s relatives regarding the results of E-light treatment, we asked the relatives to give the treatment results an overall score from 1 to 4. We considered results excellent when the score was 4, good when the score was 3, fair when the score was 2, and poor when it was 1.

Student’s t-test and p-value were used to assess the results of the E-light treatment.

Technique

The two-handles beauty machine was used in this study. It is manufactured by Beijing Oriental Wison Mechanical & Electronic Co. Ltd. It is worth mentioning that there are several similar machines available from other companies that can be used and will give the same result (Fig. 1). Local anaesthesia with Xylocaine 2.5% cream was applied for 30 minutes to the treatment area before the E-light session. All patients received sessions at 2-4 week intervals. Sessions stopped when there was an overt decrease in scar firmness, redness and itching. The number of sessions each patient needed was recorded.

The intense pulsed light (IPL) element of E-light was used with different filters according to skin colour to avoid complications; 530 nm, 560 nm, 580 nm, 630 nm and 755 nm. IPL fluence varied between 40-44 J. The spot diameter was 8-32 mm. Pulse durations were from 2-7 milliseconds and pulse delays from 15-30 milliseconds. The fluxes of the RF element of E-light varied between 10 and 12 J.

A soothing cream was applied three to four times a day for 2-3 days in order to manage the expected post-treatment itching and edema. Patient photography and post-treatment VSS assessment were done one month after their last treatment session. The patients were followed up monthly. The follow-up period in the patient inclusion criteria was a minimum of one year after their last treatment session.

Results

In this series, the age of the patients ranged from 2-12 years. There were 16 females and 49 males. Regarding the Fitzpatrick skin type classification, two of our cases were type I
two cases were type II, 33 cases were type III, 20 cases were type IV and 8 cases were type V.

The type of trauma was scald burn in 100% of our patients. The period between the beginning of E-light treatment and burn trauma ranged from 7 to 11 weeks. The number of E-light therapy sessions varied between four and eight sessions according to the patient’s response. The authors stopped treatment sessions when the scar showed a reduction in firmness, itching and elevation, with the colour becoming close to normal skin colour.

Forty-three parents (approximately 66.15%) rated their satisfaction with the result excellent, sixteen (approximately 24.61%) rated it good and six (approximately 9.23%) rated it fair. There were no poor ratings from relatives regarding their satisfaction with the final result.

The mean VSS score for our patients before treatment was 7.6 and was 1.8 after treatment.

The minimum follow-up period according to this study design was 1 year. One patient came into our outpatient clinic for another complaint 5 years later, showing nice maintained results of E-light treatment and no long-term complications. Samples of our results are demonstrated in Figs. 2-5.

**Discussion**

Throughout medical history, facial scars have represented a major problem, with most of the solutions turning out to be unsatisfactory. The search for a more successful method with better long-term results, for different skin types, remains one of the main challenges facing plastic surgeons. Scar-free healing or at least the reduction of scarring as much as possible is a major goal for the treating doctors. These scars, especially on the face, represent a major functional and psychological problem in children more than adults. The treatment of such scars in children is still an unresolved problem and more challenging due to the very complex morphology of these scars. Available treatments give results that are not satisfactory for patients or their parents.

In this series, patients with Fitzpatrick skin type I and type II were a minority (3.1% for type I and 3.1% for type II) due to the racial background of the population in our locality.

The patients selected for this study were from the burn casualty unit in our university hospital to guarantee the accuracy of data collection and knowledge of the medications used to make sure that E-light was the only treatment modality used (as we were the only doctors who prescribed medicines): and

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**Table I** - Statistical analysis of the demographic data of the patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number</th>
<th>Percentage</th>
<th>Mean±SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
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<td>Non applicable</td>
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<td>2-12</td>
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<tr>
<td>Sex:</td>
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<td></td>
<td></td>
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<tr>
<td>Male</td>
<td>49</td>
<td>75.4</td>
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</tr>
<tr>
<td>Female</td>
<td>16</td>
<td>24.6</td>
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<td></td>
</tr>
<tr>
<td>Fitzpatrick skin type:</td>
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<tr>
<td>I</td>
<td>2</td>
<td>3.1</td>
<td></td>
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<tr>
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<td>2</td>
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<td>IV</td>
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<tr>
<td>V</td>
<td>8</td>
<td>12.3</td>
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**Table II** - Statistical analysis of the treatment data of the patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number</th>
<th>Percentage</th>
<th>Mean±SD</th>
<th>Range</th>
</tr>
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<tbody>
<tr>
<td>Time gap in weeks</td>
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<td>Non applicable</td>
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<tr>
<td>Number of treatment sessions:</td>
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<td>6</td>
<td>18</td>
<td>27.7</td>
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</tr>
<tr>
<td>7</td>
<td>14</td>
<td>21.5</td>
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</tr>
<tr>
<td>8</td>
<td>10</td>
<td>15.4</td>
<td></td>
<td></td>
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</table>

**Table III** - Statistical analysis of the treatment outcomes regarding VSS showing significant reduction in VSS after treatment

<table>
<thead>
<tr>
<th>VSS</th>
<th>Before</th>
<th>Mean±SD</th>
<th>After</th>
<th>Mean±SD</th>
<th>T test</th>
<th>P value</th>
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</thead>
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<td>VSS Reduction Mean±SD</td>
<td>7.6±1.9</td>
<td>5.8±1.2</td>
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<tr>
<td>VSS Reduction range</td>
<td></td>
<td>3-8</td>
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**Table IV** - Summary of parents’ (of the studied cases) opinions after E-light treatment

<table>
<thead>
<tr>
<th>Result</th>
<th>Points</th>
<th>Number of patients</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>4</td>
<td>43</td>
<td>66.15%</td>
</tr>
<tr>
<td>Good</td>
<td>3</td>
<td>16</td>
<td>24.61%</td>
</tr>
<tr>
<td>Fair</td>
<td>2</td>
<td>6</td>
<td>9.23%</td>
</tr>
<tr>
<td>Poor</td>
<td>1</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>
moreover, to decrease the time lag between the onset of hypertrophic scars and the beginning of treatment. The authors preferred to take the date of burn trauma as a fixed point to start measuring the time periods. E-light treatment began once hypertrophic scars were clinically detected.

Some of our patients took more time than others to show hypertrophic scars. It is very difficult to detect a single cause for this variation in the length of time before the onset of hypertrophic scarring, as scarring is dependent on many factors (e.g. skin type, burn depth, familial factors, etc.).

We allowed 2-4 weeks as a period between sessions, although irritation and edema periods did not exceed three days according to parents’ statements. This period was important to assure the compliance of the patients’ relatives, as our patients were from a poor economic class and many parents had to travel from distant villages for the sessions. The period between the onset of burn and the start of treatment ranged from 7 to 11 weeks in our series. Vestita et al. reported this period to be from 6 months to 18 years.7 They left 3 to 6 months between sessions. There is no guarantee that the patients in their study did not have any other form of treatment before or even between the laser treatment sessions, causing potential bias in their results. Allowing long periods of time before treatment will theoretically allow worsening of these scars and thus affect the results.

Regarding the local treatments prescribed in our study, it is worth mentioning that the authors prescribed soothing creams for two to three days after E-light sessions. This short period would never affect treatment outcomes, but it eased the itching and irritation and increased the compliance of the patients and their families.

In this series, the number of E-Light treatment sessions ranged between 4 and 8. This wide range was due to a variation in the skin type of our patients. Theoretically, scarring will be worse the darker the skin colour, and thus needs more sessions. Our results hinted that the darker skin colour was, the more treatment sessions were needed. Unfortunately, it is difficult to prove such a correlation as a large number of patients for each

Fig. 2 - 6-year-old boy with facial post burn hypertrophic scars. a) Pretreatment front view; b) pretreatment RT oblique view; c) pretreatment LT oblique view; d) four weeks post treatment front view; e) four weeks post treatment RT oblique view; f) four weeks post treatment LT oblique view.

Fig. 3 - 10-year-old boy with facial post burn hypertrophic scars. a) Pretreatment front view; b) pretreatment RT lateral view; c) four weeks post treatment front view; d) four weeks post treatment RT lateral view.

Fig. 4 - 5-year-old boy with facial post burn hypertrophic scars. a) Pretreatment LT lateral view; b) four weeks post treatment LT lateral view.
Fitzpatrick skin type is needed so that researchers can detect an average number of sessions for each skin type. As in every locality, there are common as well as rare skin types; maybe a multicenter study could give more accurate results regarding this issue.

A period of 4 weeks was allowed after the last treatment session and before post-treatment assessment and data collection to assure a full resolution of post E-light edema and redness.

The difference in VSS before and after E-light treatment was statistically significant (mean VSS reduction was 5.8). Unfortunately, the effects of E-light treatment on each element of VSS cannot be assessed as the scarring process is multifactorial (affected by factors like race, heredity, nature of trauma, depth of trauma and the site of trauma). The study of the effects of E-Light treatment on, for example, scar pigmentation, as an isolated variety, is statistically nearly impossible.

Moisturizing, massage, silicones and pressure therapy were the main lines of treatment in a national survey of pediatric post-burn scar management in the UK, while laser, ultrasound and steroid therapy have been sporadically.3 Karagoz et al. compared onion extract based gel (contractubex) with silicone gel and sheets in the treatment of post-burn hypertrophic scars. They found silicone gel and sheets more effective but both silicon products and contractubex need multiple applications for long periods and can be rubbed off by clothes. Moreover, silicone products are expensive.16

Silfen et al. presented a case report of facial post-burn hypertrophic scars in the mental area treated by excision, abrasion to the subdermal level (even to muscle surface) and full thickness skin grafting. They termed it subdermabrasion, but unfortunately, postoperative bruising and hypertrophic scars at the edges of the wound complicated the procedure.2

Intense pulsed light (IPL) was successfully used as a single treatment modality to prevent and treat hypertrophic scars and keloids.17 Conversely, Hultman et al. reported the treatment of post-burn scars by IPL to provide minimal improvement, variable efficacy, high cost for the patients and probable recurrence of hyperpigmentation following ultraviolet light exposure.18

Khandelwal et al. reported successful results with the use of ablative fractional photothermolysis in the treatment of post-burn hypertrophic scars with statistically significant (2.2) mean decrease in VSS score.7 The use of CO2 laser by Zadkowski et al. gave similar results.5 Vestita et al. reported promising results with 595nm PDL, but they treated all kinds of scars and didn’t treat one special kind. Scars of different aetiologies differ in their characteristics and responses to treatment. They treated keloids and hypertrophic scars. They treated various ages and body areas. Finally, the scar age period before laser treatment showed a very wide range (6 months to 18 years).7

Pinheiro et al. compared the histological examination of post-burn hypertrophic scar tissue treated with RF with an epidermal temperature below 40ºC versus no RF treatment with biopsy of normal skin taken as a control (treatment area and control biopsies were taken from the same patient). The treated area showed collagen fibre density in the papillary and reticular dermis similar to normal skin while it was significantly denser in the area of no RF treatment.19 The mechanism of action of RF stimulation of collagen fibre remodelling is probably due to protein denaturation by the effect of heat followed by stimulation of collagen synthesis due to increased expression of heat shock proteins.20

Trelles et al. combined RF, ultrasound and triamcinolone transdermal delivery to treat hypertrophic scars with successful results. Unfortunately, the study had limitations as the sample number was small, and the types, morphology and extent of scars were variable. The discrimination of the effects of each of the treatments applied separately was not studied, and the effect achieved with a smaller number of treatment sessions was not properly studied.21

Shui and Hengjin used a combination of microplasma RF and triamcinolone transdermal delivery to treat hypertrophic scars with successful results. Unfortunately, the study had limitations as the sample number was small, and the types, morphology and extent of scars were variable. The discrimination of the effects of each of the treatments applied separately was not studied, and the effect achieved with a smaller number of treatment sessions was not properly studied.21

Despite the reported successful results of using several laser types in the treatment of post-burn hypertrophic scars,5,6 E-light is still advantageous over laser, in our opinion. The costs of using E-light are much lower than laser costs, and thus it is usually more suitable for burn patients as a good percentage of them come from low socioeconomic classes. Also, the spot diameter in E-light is 8-32 mm, while in different laser systems it is usually not more than 10 mm. This relatively large spot size adds to the economic value of E-light, besides its effectiveness, when compared to laser, especially in post-burn hypertrophic scars with a large surface area. The combination of IPL with RF allows the use of lower amounts of energy for treatment, and so decreases melanin absorption, decreasing complications in general. These lower energy requirements make E-light safer and can cover a broader variety of patients by being suitable for darker skin types.

Huang et al. reported the ability of most cell organelles to absorb light.23 The effects of IPL depend on the broad wave-
length spectrum (500 – 1200) of the IPL component of E-light that targets a wider variety of cell chromophores through thermal action. It is not limited to one chromophore like laser. Thus, IPL works on an even wider range of cells than any single laser type. The effect of RF on collagen remodelling by increasing the expression of heat shock proteins has been studied before.\textsuperscript{19–20} We hypothesize that E-light (IPL / RF combination) stimulates the proliferation of fibroblasts and the laying down of new collagen through electrophotobiomodulation or electric light energy specific action (ELESA).

The use of E-light in the treatment of post-burn hypertrophic scars in pediatric facial burns is presented in this work for the first time. Our results show a significant improvement in post-treatment VSS score (mean reduction of VSS was 5.8) with an economical cost. The differences in VSS before and after treatment were statistically significant. Also, patient satisfaction rates were high.

Despite the fact that the impact of this work would have been better if we had added a control (no treatment) group, we believe we could not have made such a comparative study.

### Conclusion

The technique presented in this article, using E-light in the treatment of facial post-burn hypertrophic scars in children, has proved to be effective, with a marked improvement in VSS score. It is also safe, with no reported complications, and more economical than other treatment modalities.

### BIBLIOGRAPHY


### Level of evidence. Case series (level IV)

### Conflict of interest.

The authors state that there was no conflict of interest of any kind, according to the International Committee of Medical Journal Editors’ Regulations. The brand and trade name of the IPL/RF machine used in this study was mentioned for documentation purposes only. There are many similar machines available from different manufacturers. Any of these machines can give the same effects as long as they can emit simultaneous RF and IPL energy with the same parameters.

### Acknowledgement.

The authors acknowledge Dr. Ahmed Bahaa Eldin (Professor and Head of the Plastic and Reconstructive Surgery Department, Al Mansoura Faculty of Medicine, Egypt) for his valuable efforts as an objective assessor of the results of this work.