Ablative Fractional Laser Resurfacing Helps Treat Restrictive Pediatric Scar Contractures

abstract

Conventional management of debilitating pediatric scar contractures, including hand therapy and surgery, may often be beset by delayed treatment, suboptimal results, and additional surgical morbidity. Ablative fractional laser resurfacing is an emerging adjunctive procedural option for scar contractures because of its promising efficacy and safety profile. However, its use to improve function has not been studied in the pediatric population. Herein we report 2 pediatric patients with recalcitrant scar contractures, causing persistent functional deficits, treated with an ablative fractional laser protocol. Both patients experienced rapid and cumulative subjective and objective improvements in range of motion and function as measured by an independent occupational therapist without reported complications. We highlight ablative fractional laser resurfacing as a novel and promising tool in the management of function-limiting scar contractures in children and propose that the technique be incorporated into existing scar treatment paradigms, guided by future research. *Pediatrics* 2014;134: e1700–e1705

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KEY WORDS

carbon dioxide, contracture, fractional, function, hand, laser, pediatric, scar, therapy

ABBREVIATIONS

AFR—ablative fractional laser resurfacing
DIP—distal interphalangeal
PIP—proximal interphalangeal
ROM—range of motion

Dr Krakowski conceptualized and designed the study, acquired data from patient interaction and procedures, and reviewed and revised the manuscript; Ms Goldenberg conceptualized the study, drafted the initial manuscript, and reviewed and revised the manuscript; Dr Eichenfield conceptualized the study, acquired data from patient interaction and procedures, and reviewed and revised the manuscript; Ms Murray conceptualized the study, designed the independent data collection instruments, coordinated and supervised independent data collection and analysis, and reviewed and revised the manuscript; Dr Shumaker conceptualized the study and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

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Scar formation after surgery or trauma remains an immutable step in the wound healing process. Rehabilitation may be complicated by hypertrophic scars that form contractures and adhesions with underlying tissue, binding affected musculotendinous units. Scarring may result in poor tissue pliability, increased work needed to move adjacent joints, and limited range of motion (ROM) with true functional deficits.

Aggressive hand therapy remains the mainstay of treatment within the first year after injury or reconstruction.[1,2] After an extended period of time to allow spontaneous scar maturation, surgical intervention in the form of tenolysis, flaps, and grafts may be considered for refractory deficits, although such interventions may come with treatment delay, significant surgical morbidity, and high recurrence rates.[1–4] Besides adjunctive options such as corticosteroids and occlusive dressings, there are few interventions between "therapy" and "additional surgery" with proven efficacy in treating contractures with functional limitations. A significant therapeutic void affects numerous pediatric patients worldwide with functional limitations from scars, for whom restoration to objective normalcy as early as possible should be the therapeutic goal.

Ablative fractional laser resurfacing (AFR) is an emerging therapy for skin scar contractures in adults. Recent reports suggest that AFR can result in consistent enhancements in appearance, function, and symptoms, such as pain and itch, in severe traumatic scars.[5–9] Herein we demonstrate objective functional improvements in 2 pediatric patients with debilitating scar contractures treated with AFR. Their ROM gains occurred after both had plateaued with traditional interventions (ie, therapy and surgery) and coincided temporally with laser surgery (Figs 1 and 2). We propose AFR as a promising adjunct to established contracture scar interventions in the pediatric population, guided by future research.

CASE REPORT

Preoperative Assessment

Patient 1

An 18-year-old, left-hand-dominant man presented with a third-degree burn on the right palm that he sustained from gripping a hot iron at the age of 3 (scar age = 15 years). The injury was initially treated by the local burn center using partial thickness skin grafts. The hypertrophic scar caused subjective pruritus and "irritation" to the patient. Contracture bands had also formed between the web space of his first and second digits and longitudinally along his second and fifth digits. The contractures limited his ability to fully extend his right hand, causing him difficulty grasping and opening objects. The patient's functional deficit led to significant psychosocial impact and a reluctance to participate

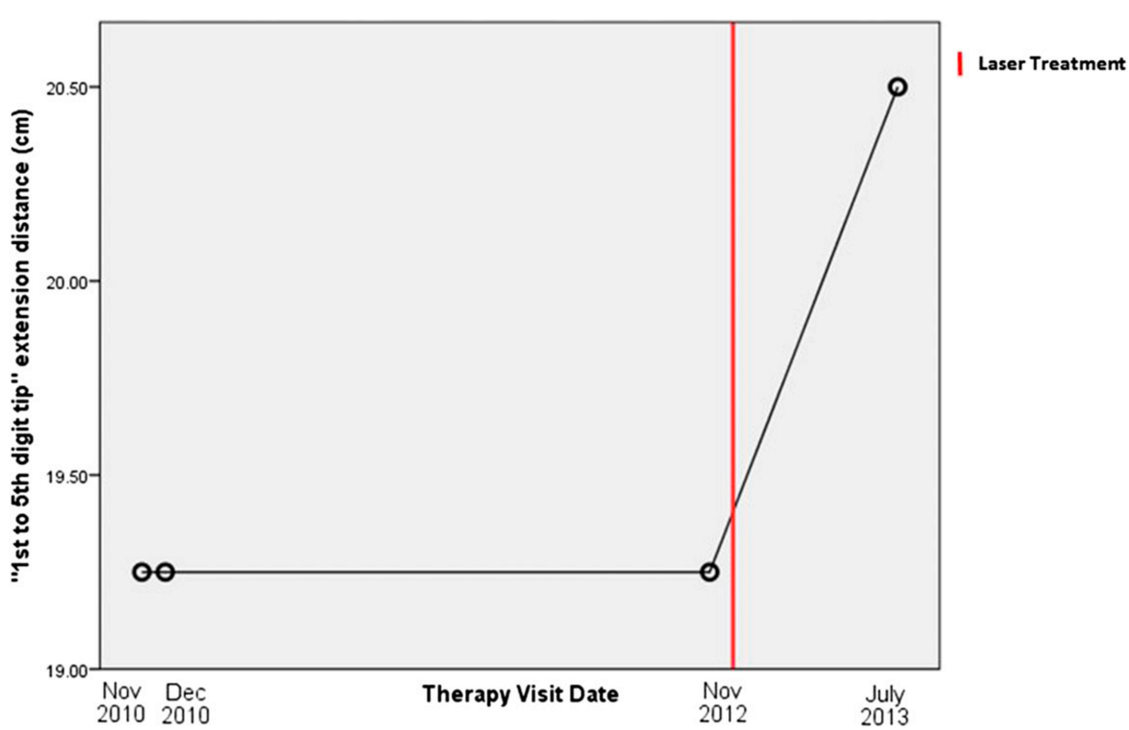

FIGURE 1
Effect of AFR on hand (1st to 5th digit) opening: Patient 1's functional improvement with AFR (scar age = 15 years) after reaching a 2-year treatment plateau with occupational therapy. After a single laser session, he demonstrated a 1.25-cm gain in palmar extension, and his right hand grip strength improved by 8 lb from baseline. Functionally, he could grasp objects 5 inches in diameter (increased from 4 inches) and could finally open a jar of peanut butter on his own.

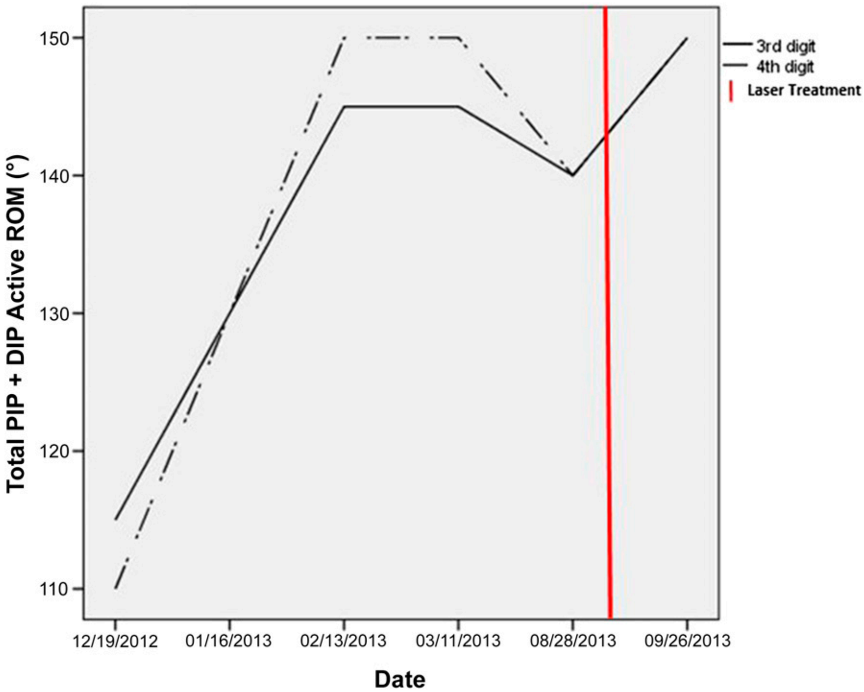

FIGURE 2
Effect of AFR on active ROM: Patient 2's functional improvement with AFR (scar age = 8 months) after a 6-month treatment plateau with occupational therapy. After a single laser session, she demonstrated a 10-degree total active ROM (DIP + PIP) gain in the right third and fourth digits. Functionally, she could grab and release a ball and appeared to use both hands equally.

in activities with his peers. Failing to show progress after nearly 2 years of dedicated hand therapy and splinting, he was referred for AFR. Preoperative functional assessment performed by an independent certified hand therapist demonstrated objective limitations in his ROM and functional use of the involved right hand as compared with his uninvolved left hand (Table 1).

Patient 2

A 2-year-old girl (hand dominance unknown because of her age) presented with burnlike injuries on the volar surfaces of her right hand after a treadmill accident at the age of 16 months (scar age = 8 months). Her wounds healed entirely by secondary intention, and she developed contractures significantly affecting the distal interphalangeal (DIP) and proximal interphalangeal (PIP) joints of her right third and fourth digits (Fig 3). Despite daily massage, stretching, and therapy with splinting, she had reached a 6-month plateau in her ROM improvements. Because of her young age, the patient was determined to be at specific risk for major functional deficits and was referred for AFR. Preprocedure assessment performed by an independent certified hand therapist demonstrated worsening PIP and DIP contractures of the right third and fourth digits as compared with those of the uninvolved left hand (Table 1).

Laser Surgery Technique

After informed consent was obtained, the scarred areas were treated with an ablative microfractionated 10 600-nm CO_2 laser (Ultrapulse Encore Deep FX; Lumenis, Ltd, Yokneam, Israel). This wavelength is avidly absorbed by tissue water, and the laser pattern generator creates narrow (~120 μm) columns of tissue vaporization with a thin rim of coagulation in a pixelated pattern in

TABLE 1 Independent Certified Hand Therapy Assessments: Preoperative and Postoperative Certified Hand Therapy Assessments of Both Patients Including Their Unaffected Left Hands, Which Served as Internal Controls

	Unaffected Left Hand	Right Hand Before Laser	Right Hand After Laser
Patient 1			
1st digit tip to 5th digit tip extension distance (cm)	23	19.25	20.5
Grip strength (lb)	105	95	103
Post-AFR subjective improvement	Decreased itch and irritation		
Post-AFR objective improvement	1.25-cm gain in palmar extension		
Post-AFR functional gain	Can grasp objects 5 inches in diameter (increased from 4 inches); can open a jar of peanut butter		
Patient 2			
3rd digit PIP joint total active[a] ROM (°)	100 (0–100)	85 (15–100)	90 (10–100)
3rd digit DIP joint total active[a] ROM (°)	90 (0–90)	55 (5–60)	60 (0–60)
4th digit PIP joint total active[a] ROM (°)	100 (0–100)	85 (15–100)	90 (10–100)
4th digit DIP joint total active[a] ROM (°)	90 (0–90)	55 (5–60)	60 (0–60)
Grip strength (lb)	Normal[b]	Weak[b]	Normal[b]
Post-AFR subjective improvement	Decreased tightness[b]		
Post-AFR objective improvement	10° improvement in total active[a] ROM (PIP + DIP) in 3rd and 4th digits		
Post-AFR functional gain	Can grasp and release a ball; uses hands equally		

[a] *Active* ROM refers to movement produced by one's own muscle (in contrast to *passive* ROM, which refers to movement produced by an external force).
[b] As assessed by certified hand therapist (patient too young to use standardized measurement devices or give subjective opinions).

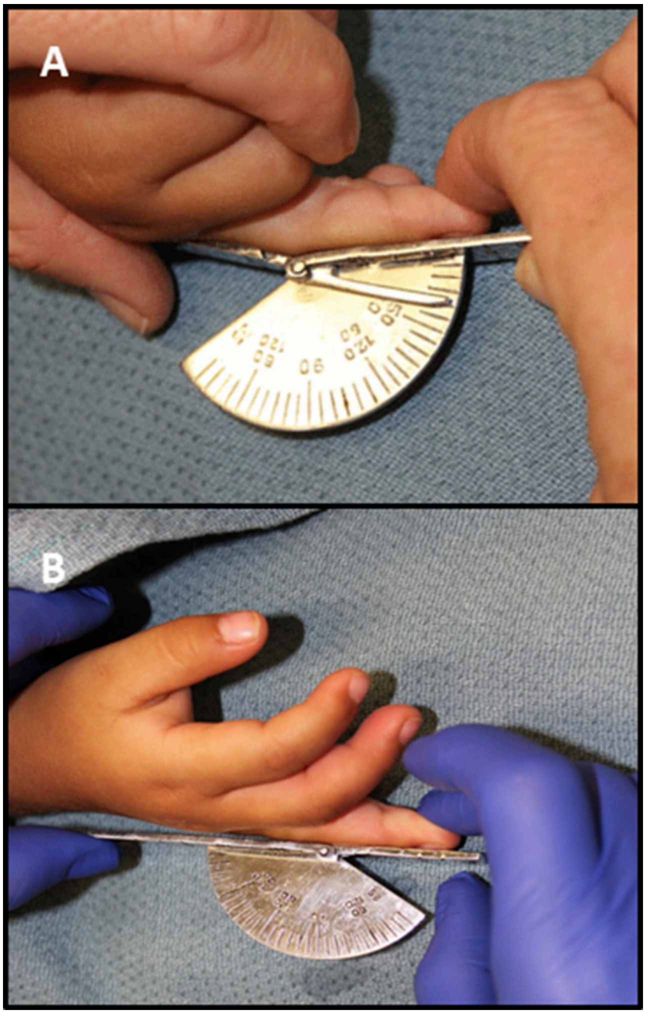

FIGURE 3
Patient 2 before and after laser intervention. A, Immediate preoperative assessment demonstrating >5° restriction in passive extension at DIP of right fourth digit. B, Immediate postoperative assessment demonstrating no restriction in passive extension at DIP of right fourth digit; this gain in ROM persisted until the patient's occupational therapy appointment nearly 1 month later.

the treatment area. For patient 1, anesthesia was provided with topical lidocaine 4% cream applied under occlusion for 1 hour and was supplemented preoperatively with ice and 12 mL of intralesional 1% lidocaine without epinephrine and without sodium bicarbonate. Patient 2 was placed under general anesthesia because of her age and the extent and depth of her injuries. Laser settings were individualized with treatment depths proportional to the estimated scar thickness. The entire scar sheets were treated with a single-pulse, nonoverlapping stamping technique at pulse energies ranging from 30 to 100 mJ (corresponding to treatment depths of ~1–3 mm, respectively) and low corresponding treatment densities of 5% to 3% to avoid excessive thermal injury. This percentage describes the total ablated surface area within a 1-cm square treatment pattern. Stated another way, 95% to 97% of the tissue within the square pattern remained untreated (Fig 4). Because of her degree of scar hypertrophy, patient 2 also received topical triamcinolone acetonide suspension (40 mg/mL) immediately after laser treatment to facilitate delivery by capillary action through the ablative columns. Immediately after all treatments, a petrolatum-based ointment was applied (Aquaphor ointment; Beiersdorf, Inc, Wilton, CT) and continued 2 to 3 times a day until complete reepithelialization occurred within ~2 to 3 days. No postoperative complications were reported, and both patients were able to resume essentially normal activity the same day.

Postoperative Assessment

Patient 1

Approximately 5 months after his initial laser surgery, the patient underwent postoperative functional assessment, performed by an independent certified hand therapist (Table 1). With a 1.25-cm gain in extension, he could now grasp objects 5 inches in diameter (increased from 4 inches), and his right hand grip strength improved by 8 lb from baseline. He reported decreased pruritus and irritation and a feeling of "independence" at "finally being able to open a jar of peanut butter" on his own. The patient declined additional laser treatments at this time because he believed his right hand was "almost as good as the left."

Patient 2

The patient underwent postoperative functional assessment, performed by an independent certified hand therapist ~1 month after her initial laser surgery (Table 1). The patient demonstrated a 10-degree total active ROM (DIP + PIP) gain in the right third and fourth digits.

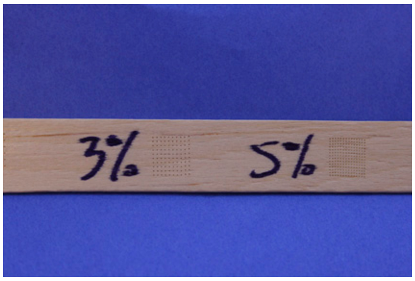

FIGURE 4
Tongue depressor after treatment with AFR depicting a "stamped" square pixelated pattern and demonstrating the difference between density settings of 3% and 5%.

Functionally, she could now grab and release a ball and appeared to use each hand equally. Her therapist noted marked decrease in scar "tightness." Continued AFR treatments, occupational therapy sessions, at-home massaging, and splinting are planned.

DISCUSSION

Herein we describe the use of AFR as an effective and minimally invasive intervention to improve ROM and overall function in 2 pediatric patients with refractory scar contractures. It is not entirely intuitive that a pixelated thermal injury to a scar contracture could result in rapid subjective and objective improvements.[10] However, unprecedented treatment depths (up to 4 mm with current devices) combined with tissue sparing adjacent to ablative columns probably facilitates rapid reepithelialization and provides ample viable cells to drive a vigorous remodeling response while maintaining excellent safety margins.[11–15] Gains in ROM observed in the immediate postoperative period probably derive from photomechanical fenestration of stiff scar tissue. Long-term, persistent gains in function and improvements in scar characteristics probably result from gradual diffuse dermal remodeling and a relative normalization of dysfunctional scar tissue.[5]

Despite the promising findings, there are limitations to our results, including the small sample size, the heterogeneity of the patients and treated scars, and the lack of a treatment control. The varied nature of trauma itself confounds the attempt to generate a coherent series at a single center in a reasonable length of time. Therefore, this report is presented to offer a range of potential applications for the procedure and to help stimulate additional research. Although these variables limit the ability to compare improvements through more detailed statistical analysis, the fact that the patient characteristics are so varied actually supports the notion that AFR may help modify ROM and functional deficits in a diverse group of scars. Because of the absence of controls we cannot fully ascribe the improvements in function to AFR alone because some improvement may have simply occurred spontaneously over time. However, both patients achieved rapid improvements within days of the initial treatment, despite scar ages of 15 years and 8 months, respectively. Pretreatment measurements in these cases may serve as a baseline with which to compare objective posttreatment gains. The strong temporal association between stable pretreatment deficits and rapid posttreatment improvement provides compelling anecdotal evidence for efficacy and a form of internal control. Although pretreatment and posttreatment histologic comparison would potentially have supported laser-induced scar remodeling as a mechanism of action in these cases, it was thought that the risk of biopsy was counterproductive in these clinical situations.

The use of laser-assisted delivery of triamcinolone acetonide suspension in patient 2 merits specific discussion. Triamcinolone, a corticosteroid, has long been used to help soften and flatten hypertrophic scars and keloids, and its topical use immediately after AFR in the same session has recently been reported to be effective in the treatment of hypertrophic scars.[16] It is likely that corticosteroid therapy contributed to a portion of the improvement observed in patient 2. However, the rapidity and degree of functional improvement after treatment argues against the exclusive role of corticosteroids. Furthermore, the concept of laser-assisted delivery of medications through ablative microchannels raises exciting possibilities for the delivery of a wide variety of substances below the epidermal barrier to the area of interest.[17] Without laser pretreatment, a single application of topical corticosteroid suspension alone would have had minimal effect on the underlying scars.

This report highlights the novel application of AFR in the pediatric scar contracture population, where the concept of "use it or lose it" is an unfortunate reality. Large prospective studies are warranted to help confirm the technique's efficacy and safety, elaborate appropriate treatment parameters and timing, and identify potential combination therapies. Future studies may even elucidate whether early intervention with AFR has a role in mitigating or preventing contracture development, perhaps saving resources and limiting overall disability.

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