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Measurement of change in the mechanical properties of burned skin to therapist intervention with a vacuum device☆

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ABSTRACT

Introduction: The currently available clinical scales used to describe healed burn wounds have limitations. Quantitative measurement of the outcomes from burn therapy treatment would be useful in planning clinical care, resource allocation and research. The purpose of this study was to observe the measurements of a portable materials testing device before and after burn therapist intervention for closed burns.

Methods: A recording was taken using a hand-held vacuum device to measure deformation of the skin in the same location prior to and following a treatment session with a burn therapist in an outpatient clinic at a tertiary burn center.

Results: Twenty-eight subjects were recruited to the study. Statistically significant differences were noted in modulus and elasticity change between sheet and meshed split thickness autografts ($p = 0.0233$). Positive change in modulus was correlated with increasing therapy time ($R = 0.46$), specifically for meshed grafts ($R = 0.70$). Positive change in modulus was noted in therapy time greater than 48 min.

Conclusions: Quantitative measurement of the outcomes of burn therapies on the mechanical properties of healed burns is possible in an outpatient clinic setting. Improvement in the stiffness of burn scars was observed in treatment sessions that last at least 48 min.

1. Introduction

Outpatient burn rehabilitation can be a lengthy and costly process [1]. In the current clinical environment, the use of quantifiable metrics for treatment outcomes may influence patient access to care and practitioner reimbursement. Unfortunately, commonly used clinical burn scales such as the Vancouver Scar Scale have limitations because they are very limited as such are not reasonable to use as outcome measures for scar research. As a specific example, inter-rater reliability measured by intra class correlation coefficient of both the total modified Vancouver Scar Scale and the individual sub scales on established burn scars has been

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reported as low as 0.07–0.50 [2,3]. Therefore, it would be beneficial for burn care providers to have access to reliable and valid instruments that provide high quality data regarding change in burn scars due to interventions.

The use of electronic instruments may be more reliable and valid than the subjective clinical scales used today [3]. Several individual characteristics of burn scar such as erythema, volume, mechanical properties or texture may be measured independently with different devices. Other clinical characteristics such as itch or pain may also be measured with specific scales or tools that are not amenable to measurement through electronic instrumentation [4].

As of now, there is no single clinical tool nor instrument that will capture all of the characteristics of burn scar combined. In reality, such a tool or scale is practically impossible as there is likely no meaningful way to combine a subjective experience such as pain with a physical characteristic such as pigmentation or stiffness. Therefore, as treatments are investigated to address specific aspects of burn scarring, we propose that a specific instruments are applied as an outcome measure for a specific burn scar characteristic rather than attempting to develop a single all encompassing burn scar tool.

Several instruments have been devised to attempt to measure the viscoelastic properties of skin and scars *in vivo* using a variety of techniques such as the application of torsion or friction to the skin or measurement of shear or elastic wave propogation [5]. Vacuum device materials testing systems apply a negative pressure in a closed space and the amount of skin that is drawn in to the chamber is measured with reflected light. The use of a vacuum device has been demonstrated to reliably distinguish between normal skin, skin graft donor sites and hypertrophic scars following burns with acceptable inter-rater reliability [2,3].

Verifying the validity of the device in a laboratory setting poses some challenges as an *in vitro* sample of excised human skin or scar would have significantly different viscoelastic properties than skin in vivo [5]. However, other investigators have attempted to address the issues of reliably and validly measuring mechanical properties of human skin *in vivo* in several different ways.

In one example, measurements were taken of subjects with normal skin between 12 and 82 years old and the outcomes measured were consistently correlated with increasing age. In this study, healthy subjects had measurements taken with a suction device (Cutometer, Courage - Khazana^{TM}) on the temporal region and the forearm. Specifically, residual skin deformation after release of suction (elasticity) was significantly different amongst young men (mean 18.7 ± 5.4 years) and women (mean 20.7 ± 5.5 years) compared with elderly men (mean 70.9 ± 7.2 years) and elderly women (mean 67.8 ± 6.8 years) [6].

In another study, researchers compared a suction device with a topographic photo scale to estimate increasing elasticity of the skin with increasing age. Facial skin on women between 20 and 61 years was tested using a suction device and an image created for measurement using a Moire's topographic scale. Increasing age correlated with decreased elasticity (Pearson $r = -0.687$ to -0.725) [7].

Instead of age, other investigators have considered testing vacuum devices in fibrotic skin conditions. In one such project people with systemic sclerosis had measurements taken using a cutometer in 74 different anatomic regions and the data was compared to a clinical scleroderma scale. The intraobserver correlation coefficient was reported as 0.94 and the Spearman rank correlation between the Cutometer and clinical scale was 0.69 [8]. In another investigation, researchers compared suction device measurement to clinical assessment of the pliability in established burn scars. They found that the intraclass correlation coefficient for measurement using the device for elasticity was 0.76. The correlation between the elasticity measurement and the subjective pliability score was statistically significant ($p = 0.001$) although the overall agreement was moderate ($r = 0.53$) [9].

When a negative pressure is applied to normal human skin or scar, there are two major phases of deformation. First, an elastic phase of stretch at low pressure where the skin is drawn up through the device aperture. Then, there is a linear increase in deformation with increasing negative pressure that peaks either at a pre-set limit as defined by the user or the ultimate mechanical strength of the skin that results in failure. Provided the skin remains intact throughout testing, upon release of the pressure, the skin or scar then is expected to return to its pre-testing state [5]. As such, several descriptors of the mechanical properties of the skin may be calculated. A typical stress–strain curve is depicted in Fig. 1. The elastic modulus, or the slope of the stress–strain curve represents a measure of stiffness in a material. A higher elastic modulus implies a stiffer material. In a normal skin animal model, modulus varies by thickness and anatomic location [10]. Elasticity is measured by the BTC-2000 as the recovery in mm that happens when the negative pressure is released.

This study was undertaken to explore the response of healed burned skin to a single therapy session using a vacuum device as described above (BTC-2000, SRLI Technologies).

We estimated that a minimum of $N = 28$ testing sites would be needed to detect a 30% difference in modulus between pre- and post treatment groups with 80% power and a type-I error rate of 0.05. Because there is no standard existing data comparing differing burn scars in various anatomic locations in humans, we did not restrict testing to any one specific anatomic region other than it had to be amenable to stretching. We anticipated that the post-treatment skin would be less stiff than the pre-treatment skin.

2. Methods

This study was approved by the University of Texas Southwestern Medical Centre at Dallas Institutional Review Board. All subjects provided written, informed consent to participate in the study. Adult subjects with healed burns that were participating in ongoing physical or occupational therapies that presented to a university based outpatient clinic were recruited in to the study. The enrollment criteria and anatomic site selection considerations are presented in Table 1.