BURNS 41 (2015) 789–795

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# Alteration of biomechanical properties of burned skin

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ARTICLE INFO

*Article history:*
Accepted 25 September 2014

*Keywords:*
Burn
Cutometer
Skin elasticity

ABSTRACT

*Background:* The prevalence of burns in the general population is high. Despite new research findings, skin burns and its resulting tissue damage are still not entirely understood. In particular, little is known about the depth-dependent alteration of skin biomechanical properties of these wounds.

*Methods:* Thirty-six burn wounds with six different depths were generated on the abdomen of six Göttingen minipigs. The alteration of skin biomechanical properties was evaluated objectively after 15 and 360 min using a Cutometer device. Biopsies for histological evaluation were taken and the depth of burn was correlated with biomechanical properties.

*Results:* Firmness of skin (R0), overall elasticity (R8) and calculated elasticity (Ue) demonstrated a continuous decrease with an increasing depth of burn 15 min after wound generation. Gross elasticity (R2), net elasticity (R5) and amount of elasticity of the whole curve (R7), however, showed an increase of values with increasing depth of injury. A further decrease of elasticity was demonstrated 360 min after wound generation.

*Conclusion:* The alteration of skin biomechanical properties is a function of damaged tissue structures. The presented results demonstrate a depth-dependent decrease of principal elastic parameters with an increasing depth of burn and the results indicate progressive tissue damage over the time.



## 1. Background

In the United States, it is estimated that approximately 450,000 people sustain burns and need medical treatment per year. Approximately 40,000 of these injuries lead to hospitalization and 3400 lead to death [1]. Of these burns, 69% occur at home and 69% of the people involved in are male [1].

According to the damaged skin layers, burn wounds can be divided into epidermal (1°), superficial partial-thickness (2a°), deep partial-thickness (2b°) and full thickness wounds (3°). Full thickness wounds also include destruction of the hypodermis. Treatment approaches differ according to the depth of damaged skin layers [2]. Epidermal injuries such as sunburns do not require specific surgical treatment and regenerate without scarring. Superficial partial-thickness

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http://dx.doi.org/10.1016/j.burns.2014.09.021

burn wounds heal by epithelialization from the wound margins where basal keratinocytes change into a proliferating migratory cell type. Epithelial cells migrate either from the wound edge, hair follicle [3–5] or from sweat gland remnants [2,6]. Deep partial-thickness injuries take longer to heal and scarring is more pronounced. To date, the first choice for treatment of deep burn and full thickness wounds is still the transplantation of autologous split thickness skin grafts [7–9].

Since the first descriptions of non-invasive quantification of the elastic properties of skin through a hand-held device in 1988 by Bartell et al. [10], research of biomechanical skin changes in burns has generally focused on scar formation or the comparison of different therapeutic regimens. New research findings improve the understanding of burns [11,12]. However, the exact mechanism of burn and the resulting tissue damage are still not entirely understood.

Clinical evaluation and exact determination of the burn's depth are still a diagnostic challenge. Thus, the initial evaluation of burn is frequently imprecise and the extent of injury still difficult to predict. An effective device for an objective measurement of burn depth is still missing. Thus, we hypothesized that the depth dependent changes in biomechanical skin properties could play a role in burn depth assessment.

In order to improve the understanding of burn and the resulting tissue damage we created an in vivo burn model (unpublished data) that allows the creation of controllable and consistent burn. As a new aspect of acute burn, depth-dependent alteration of skin biomechanical properties should be examined.

The aim of this study was to evaluate the Cutometer device in burn depth assessment and to demonstrate the burn depth-dependent changes in the biomechanical properties of skin.

## 2. Methods

### 2.1. *Animals*

All experiments were performed on 6 female Göttingen minipigs (Ellegaard A/S, Dalmose, Denmark). The minipigs were housed at the animal husbandry in groups of 6 animals. The housing's environment was adjusted to receive a temperature range of $21 \pm 1$ °C, $60 \pm 10\%$ humidity, and a 12-h on-off light cycle (9 am to 21 pm). At arrival the minipigs weighed 22.6 kg (±1.4 kg) and had an average age of 39 weeks (±12 d). They had access to water ad libitum and were fed 400 g of a standard minipig diet (SDS SMP, Special Diets Services, Witham, Essex, UK) per day.

### 2.2. *Burn model*

Based on the findings of Henriques and Moritz, a burn model was designed [13,14]. At first the animals were premedicated with an intramuscular injection of azaperone (Stresnil®, Janssen Animal Health, Division of Janssen-Cilag GmbH, Neuss, Germany) and atropine (Atropin-100 mg Injektionslösung®, Dr. Franz Köhler Chemie GmbH, Bensheim, Germany). Butorphanol, ketamine and medetomidine (Dorbene vet Injektionslösung®, Pfizer GmbH, Berlin, Germany) were applied weight adapted intravenously to induce anesthesia. Furthermore, ketamine and midazolam (Midazolam-ratiopharm®, ratiopharm GmbH, Ulm/Donautal, Germany) were used to extend anesthesia.

The animals were a placed in lateral position and the abdomen was shaved. Six contact burn wounds were generated through an aluminum bar with 300 g weight and a radius of 10 mm. The aluminum bar was equilibrated in 100 °C water and was placed on skin for 1, 3, 6, 12, 30 or 60 s.

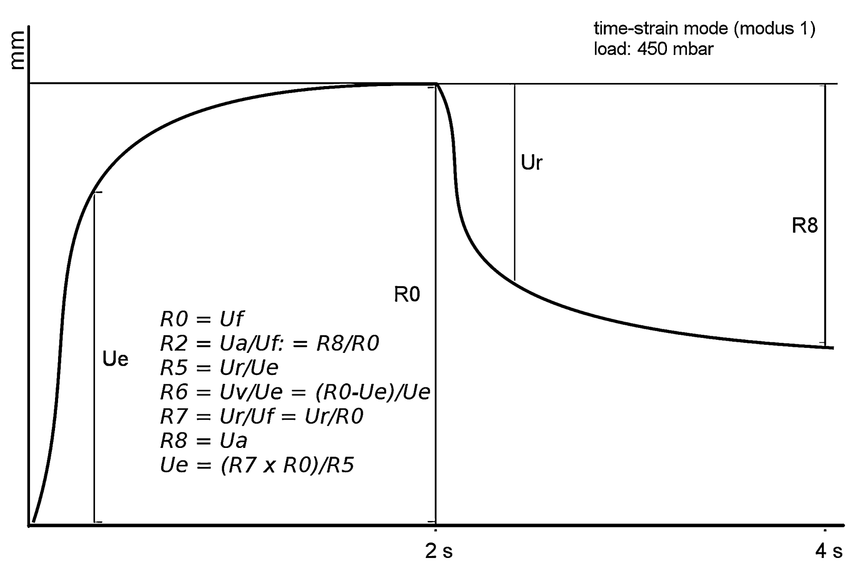


**Fig. 1 – Demonstrates the Cutometer skin deformation-time curve with an application of 450 mbar load for 2 s (on-time) followed by a relaxation time of another 2 s (off-time). For our measurements, the time-strain mode (Modus 1) and a measuring probe with an aperture of 6 mm were used. Calculated elasticity (Ue; not displayed numerically by the device), firmness of skin (R0) and overall elasticity (R8) generally were assumed to be the most representative values for skin elasticity.**