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Skin tensile strength modulation by compressive garments in burn patients. A pilot study

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Compression therapy is frequently used to prevent hypertrophy of post-burn scars. This pilot study was performed in 6 patients to assess non-invasive changes induced in the tensile strength of the skin before any clinical improvement can be perceived. Assessments were performed using a computerized suction device delivering three 5 s cycles of 500 mbar depression. Measurements were made at one-month intervals for three months after initiating the garment compression therapy. Comparisons were made between the intact skin, the ungrafted and grafted post-burn scars and the graft donor sites. Data show that garment compression therapy alters the tensile strength in the skin of all test sites. The most reliable variations consist of an increase in both the extensibility and elasticity of the tissues submitted to traction.

Introduction

Hypertrophic scars are a common complication of second degree or deeper burn injuries. Compressive garments are used to limit such tissue reactions. Clinical experience has shown the efficacy of such a treatment [1]. Objective measurements of the kinetics of improvement would be welcome in order to bring further improvements in the management of these patients.

The expected benefit of garment compression therapy on a post-burn hypertrophic scar consists of reducing and softening the connective tissue growth. For the functional part of the problem, measuring the tensile strength of the skin might appear to be a good means to objectivate the improvement. Such a non-invasive monitoring is made possible using computerized devices [2, 3]. Only a few studies have evaluated the *in vivo* tensile strength of scars using such objective assessments [4–11].

The present pilot study was undertaken to assess the effect of compressive garments on the skin tensile strength on intact areas, post-burn hypertrophic scars at grafted and ungrafted sites, and on the healing donor site of the grafts. A longitudinal survey over 3 months was chosen without enrolling untreated control patients which would not have been ethical.

Patients and methods

Six patients, victims of second degree burns, treated at the Burn Unit of the Liège University Medical Center, were enrolled in the study (table 1). Autologous grafts had been used on some burned areas in order to improve wound healing. Compression therapy using specially designed garments (Tricolast®, Deinze) was initiated a few weeks after the burns at a time when the scarring process appeared to enter a hypertrophic phase.

Objective non-invasive assessments of the skin tensile strength were made before wearing the garments and at one-month intervals for three consecutive months of compression therapy. The Cutometer SM474® (C+K electronic, Cologne, Germany) was used with a hollow probe centred by a suction aperture of 4 mm in diameter [12]. The time–strain recording was used with 3 cycles of 5 s traction under negative pressure of 500 mbar separated by 5 s relaxation phases. The biomechanical parameters were similar to those previously described [2, 12, 13]. They are summarized in figure 1 and table 2. In each patient, measurements were taken on different sites, which were kept identical at each evaluation time. Data were tabulated in four distinct groups, namely, ungrafted post-burn scars, grafted post-burn scar, healing donor site of graft and control normal skin symmetrical to the burns. The latter data were pooled with measurements performed on healthy skin at similar reference sites in all volunteers. These were located on the volar forearm at 17 cm from the wrist and on the lateral aspect of the arm at 5 cm beneath the acromion.

For each patient and each of the four types of lesional and healthy skin, measurements of each biomechanical parameter were averaged at each evaluation time. Data from the 6 patients were pooled and the median was calculated for each parameter. Differences and percentage variations were calculated between sites at a given evaluation time, and between the successive session assessments for each test site. Statistical comparisons were made using the non-parametric paired Wilcoxon test. The effect of garment compressive therapy over time was assessed using the Friedman test followed by the Dunn test. In the case of significant changes, regression analysis models were applied to evaluate the best fitted relationship, either linear, logarithmic, exponential or power. The coefficient of correlation r was calculated. For all statistical tests, a p value lower than 0.05 was considered significant.

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Table 1. Patients under garment compressive therapy (GCT).

Patient	Gender	Age	Burn Type	Burn Extent (%)	Post-burn duration before GCT (month)
1	M	26	flame	13.5	5
2	M	27	chemical	7	6
3	M	41	water	9	2
4	M	47	flame	15	1.5
5	M	56	flame	14	3.5
6	F	51	contact	3	3.5

Table 2. Tensile parameters.

Elevation
MD, maximum distension
VER, viscoelastic ratio = 10^2 (MD1 — ED1) $ED1^{-1}$
DD, differential distension (μm) = MD3 — MD1
Retraction
RER, relative elastic recovery = 10^2 (MD1 — ER1) $MD1^{-1}$
BE, biological elasticity = 10^2 (MD1 — RD1) $MD1^{-1}$
EF, elastic function 10^2 (MD1 — ER1) $ED1^{-1}$

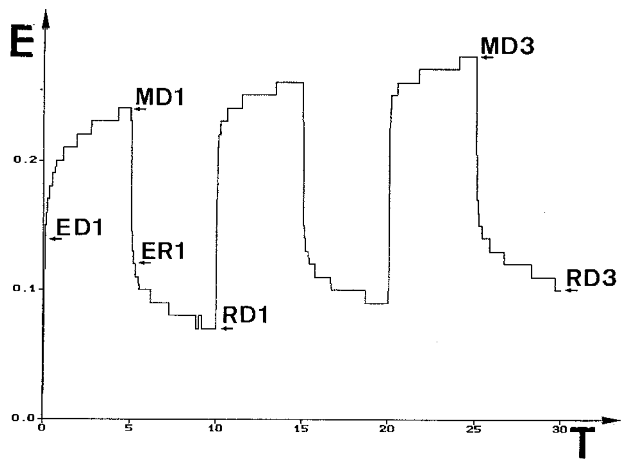

Figure 1. Example of skin deformations induced by three 5 s cycles of 500 mbar suction applied to an area of 4 mm in diameter. Elevation (E) of the skin is recorded in time (T). See text for the depicted parameters.

Table 3. Tensile strength of the skin according to the test site before entering the garment compression therapy. Values represent the median percentages of variation compared to normal control skin (100%).

Tensile property	Ungrafted post-burn scar	Grafted post-burn scar	Graft donor site
MD	41	39	64
DD	49	37	43
BE	86	82	90
VER	67	53	66
EF	50	51	61
RER	58	65	71

Results

Between site comparisons at entry in the study

When the patients were asked to enter the garment compression therapy, the tensile strength of the skin was markedly different on the scars compared to the normal control sites (table 3). MD and DD were markedly reduced at the lesional sites, particularly the post-burn scars. EF, RER and VER were also decreased on the same sites although to a lesser degree. BE was little affected by the scarring process.

Evolution of the tensile strength of the skin during garment compression therapy

The salient data are presented in table 4. Garment compression therapy resulted in MD increase at all test sites, showing almost a linear trend in time. Significance was reached on normal skin and the graft donor site. The Dunn test indicated that the effect started after the first month of therapy.

Variations in DD and VER were erratic at all the test sites and did not reach significance.

BE increased on all test sites with an exponential trend over time. Significance was reached except for on the grafted lesions. The Dunn test showed a significant change after the second month of therapy. EF also increased on all test sites with an exponential trend on normal skin.

RER showed a linear trend increasing over time, reaching significance on normal and ungrafted post-burn scars.

In the overall evaluation, the combination of MD and BE variations appeared to be the best representative aspect of the skin tensile changes occurring during garment compression therapy (figure 2).

Discussion

The tensile strength of the skin can be assessed in health and disease using various methods including stretching, elevation, indentation, vibration, torsion and suction devices. The latter approach has been extensively used to study the functional tensile properties of the dermis. However, only a few studies have addressed the problem of abnormal scarring [4–11]. The present pilot study intended to disclose some physical characteristics, if any, which could objectively show the effect of garment compression therapy on evolving hypertrophic post-burn scars.

As expected, the tensile strength was different on normal and scarring skin at entry in the study before applying compressive therapy. Our data are in line with previous reports indicating a decreased skin extensibility and altered viscoelastic properties at the site of the scars [8]. Autologous grafts used to improve wound healing [14] did not appear to influence the

Table 4. Evaluation of the tensile strength of the skin during a garment compression therapy. Data are presented in % of variation yielded after three months. When the change is statistically significant, the correlation is indicated.

Tensile property	Control normal skin	Ungrafted post-burn scar	Grafted post-burn scar	Graft donor site
MD	+38% linear, $r = 0.48$	+64%	+15%	+35% linear, r=0.39
DD	−11%	0%	−23%	+92%
BE	+9% exponential, $r = 0.21$	+3% exponential, $r = 0.21$	+6%	+12% exponential, r=0.27
VER	+7%	−8%	−12%	−10%
EF	+23% exponential, $r = 0.49$	+25%	+3%	+7%
RER	+23% linear, $r = 0.31$	+33% linear, $r = 0.51$	+10%	+11%

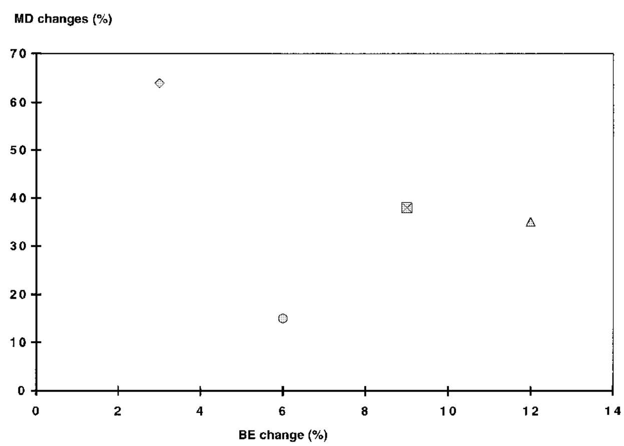

Figure 2. Scatterplot showing the mean percentage of change in maximum distensibility (MD) and biologic elasticity (BE) after a 3-month compression therapy on healthy skin (□), grafted (◇), ungrafted postburn (○), and donor graft sites (△).

tensile strength of scars compared to ungrafted lesions.

It is acknowledged that the tensile strength of the skin is influenced by the previous mechanical solicitations applied at the test site [2, 3]. The present study explores such a feature after applying sustained compression. Our data suggest a similar effect although with different intensities on healthy and damaged skin. Globally skin extensibility (MD) progressively increased while on compression treatment. Skin elasticity (BE) also showed the same trend of evolution although to a lesser degree. Such overall findings were already reported during compression therapy of oedematous legs in the gravitational syndrome [15].

The increased dynamic distensibility and elasticity after a relatively short period of compression therapy can hardly be explained by changes in the density and conformation of the connective tissue fibre networks. The mobilization of glycosaminoglycans may influence the data. A resulting reduced amount should theoretically put less static tension on the fibre networks at rest. As a result, any extrinsic superimposed force should allow apparent larger extensibility. Yet another explanation involves the natural intrinsic stress imposed by fibroblastic cells inside the dermis [16]. Any additional force such as sustained compression applied to the tissues might alter the cell biology and mechanical function.

The relevance of our findings with regard to the control of hypertrophic scarring is undecided. During wound healing, intrinsic forces imposed by myofibroblasts and fibroblasts are responsible for a retraction process. They are also likely to be a stimulus for dermal cell proliferation and accumulation. Hence, the distensibility of the skin is further decreased. Reducing the pathological limitation in static distensibility of the skin would be welcome to reverse the process of connective tissue hyperplasia. This seems to be effectively obtained using compression therapy.

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