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Çekme Gerilimi Altındaki Derinin Fiziksel Özelliklerin Tanımlanması İçin Yeni Bir Cihaz
A New Device for Describing Physical Properties of Skin Under Tensile Stress

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***Özetçe* — Deri bütünlüğünün bozulduğu, yanık, travma, kanser vb. olgularda, tedavi amaçlı kullanılan deri genişletme cerrahileri, genellikle deri altına yerleştirilen silikon bir balonun salin infüzyonu ile şişirilmesi ile gerçekleştirilir. Bu yöntemle er ne kadar doğa taklit edilmek istense de fiziksel etkinin oluşturacağı cevabın, fizyolojik sınırlarda olup olmadığının bilinmesi bu tedavinin en zorlayıcı kısmıdır. Fiziksel zorlama belirli bir değerin üzerinde olduğunda çekme-gerilim kuvvetleri ve uygulanan basınç ile kapasitenin üzerine çıktığında nekroza, ya da daha ileri seviyelerde derinin ani yırtılmasına sebep olarak balonun ekspoze olması gibi komplikasyonlarla sonuçlanmaktadır. Bu nedenle derinin fiziksel özellikleri ve uygulama esnasındaki değişimlerinin bilinmesi, patolojik bir etkinin gerçekleşip gerçekleşmeyeceği konusunda çok değerli bir öngörü ortaya koyacaktır. Balonunun şişirilmesiyle meydana gelebilecek fiziksel değişimlere cevaben optik, elektriksel ve çekme yanıtları ortaya çıkacaktır. Literatürde birçok çalışmaya ayrı ayrı bu üç yanıtın çeşitli versiyonları konu olmuş olsa da araştırmaların üçünün eş zamanlı yapılabilmesinin önündeki en büyük engel kuşkusuz senkron çalışan cihazların getirdiği kısıtlardır. Bu makalenin konusu bu anlamda yapılacak araştırmalar için kullanılabilecek efektif bir sistemin tasarımını ve yapılan testlerle geçerliliğinin ortaya koyulmasıdır..**

Anahtar Kelimeler* — *deri; rejeneratif cerrahi; derinin optik özellikleri; derinin elektriksel özellikleri; derinin çekme özellikleri; doku genişletme cerrahisi, biyomekanik

***Abstract*— Burns, trauma, cancer, etc., which deteriorate the integrity of the skin. Skin expansion surgeries that are used for therapeutic purposes with natural inspiration in cases are usually inflated with a saline infusion of a silicone balloon placed under the skin. Although imitating nature is the most challenging part of this treatment, knowing whether there is a physiological limit or not is the answer that will produce physical activity on the ground. In other words, when the physical force is above a certain value, the balloon is inflated excessively, resulting in complications such as necrosis due to impaired perfusion when the pressure effect applied to the ball by the pulling forces and balloon is over, or balloon exposition due to deep tearing at higher levels. For this reason, its deep physical properties and knowledge of the changes during application will give a very valuable insight into whether a pathological effect will occur. Optical, electrical and tensile responses will emerge in response to the physical changes that can occur in the bubble as the balloon is inflated. While many versions of these three responses are the subject of many studies separately in the literature, the biggest obstacle to the simultaneous execution of the researches is undoubtedly the low cost and high cost of synchronous devices. The topic of this article is the design of an effective system that can be used for research in this sense and the validity of the tests made.**

Keywords* — *skin; regenerative surgery; skin optical properties; skin electrical properties; skin tensile properties; tissue expansion surgery; biomechanics

I. Introduction

It is the widest organ that covers the body and covers 7% of total human body mass. Skin is an organ that has vital functions as the body covers its entire surface. Functions of the skin can be summarized, thermoregulation, sensory and metabolic functions. It is derived from ectoderm and mesoderm in embryonal life. The Skin consists of epidermis, dermis and subcutaneous layers. (*figure 1.*) The thickness of the skin layer and the structural properties varies regionally.[1]

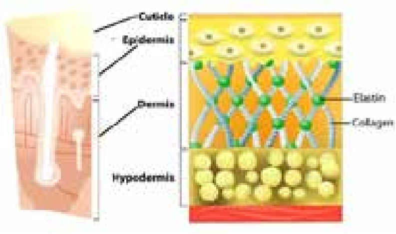

Figure 1: Skin layers and structural model

A. *Optical properties of skin*

The optical properties of the tissues reported in the literature are summarized in terms of wavelength scattering, transmittance, absorbance, emission of light behavior to the scattering of data and biological tissues.[2] In our study, we focused transmittance of skin. Transmittance is defined as the fraction of incident light which is transmitted, ie, passes

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through, a sample. A beam source has been shown to pass through an absorbing sample with *t* thickness and concentration c. The *I* (1) power at the beginning of the beam drops, I_a is photons with the absorbing particles in the environment and I_r is the reflected light from the sample. I_o stands for the transmited light. The "tranmittance" *T* (2) of the solution is the fraction passed by the medium of the incoming beam (*figure 2*).

$$I = I_r + I_a + I_o \quad (1)$$

$$T = (I/I_o) \quad (2)$$

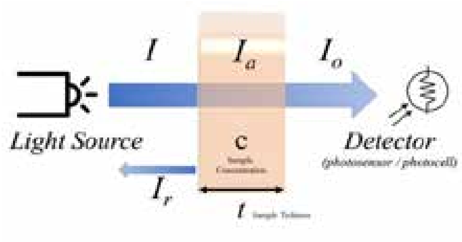

Figure 2: Light Transmittance, Absorbance and Reflection model

Tranmittance differs according to the different structural properties of fractional biological tissues [2]. But also has a heterogeneous structure due to its thickness and structural differences [3]. The transmittance varies with the wavelength of the light like the structural properties of the sample. The change in transmittance causes a change in the penetration of the resultant light. Bashdov et al. have shown that the maximum absorption in the wavelength range of 410 to 537 nm is investigated in skin tests. In addition, in the same study, it was shown that the wavelength of the light in this range is the lowest penetration, furthermore, the highest penetration and the lowest absorption is 900 to 1100 nm wavelength [4].

The Beer-Lambert law (or Beer's law) is the linear relationship between absorbance (*A*), concentration (*c*) and path length or thickness (*t*) of an absorbing specimen. ε is the wavelength-dependent molar absorptivity coefficient with units of M^{-1} cm^{-1}. The general Beer-Lambert law is usually written as:

$$A = \varepsilon \; x \; t \; x \; c \quad (3)$$

The relationship between absorbance and transmittance is;

$$A = -\log T = -\log (I / Io) \quad (4)$$

These relations (1-4) dictates to researchers thickness varies transmittance with negative correlates and positive corelates with absorbance.

B. Electrical properties of skin

This feature can be an effected easyly by hydration, structural proteins like melanin, elastin, collagen levels, live/death cell ratio, thickness, metabolic and psychological fluences [5-7]. When the human skin resistance is measured by electrodes placed on the surface of living skin, it is clear that the epidermal stratum corneum has a very large effect on the impedance because of its structural components. According to Yamamoto at al. For adequate studies of the electrical properties of the stratum corneum sould be included in the sample. In their study, they modelled skin as a resistor and capacitor connected in parallel with each other under alternative current stimulation. (*figure 3*) [8].

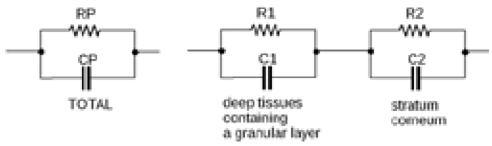

Figure 3: Equivalent circuits of skin impedance under Alternative Current

Resistance(*R* ,ohm)basically depends on three variables. Of these, the material is the resistivity. The other two variables depend on the geometry of the conductor: the length or length of the material and the cross-sectional area of the material. The resistance formula (mathematical model) is as follows:

$$R = \rho \frac{L}{S} \quad (5)$$

ρ= The resistivity of the material in ohm metres, Ω·m
L= The length of the piece of material measured in metres, m
S= is the cross-sectional area of the specimen measured in square metres, m^2

Furthermore, in biomechanical researches investigators usually study on biological specimens more in sheet form. In this form resistance calculation turns into a sheet resistance, and the equation transforms into;

$$R = \rho \frac{L}{Wt} \quad (6)$$

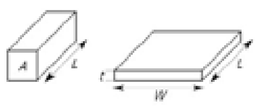

Figure 4: Geometric explanations for defining resistivity

Under tensile load or tissue expantion treatment, skin gets a higher length (*L)* and lower thickness (*t*), as a result of this phenomena skin gets a higher resistivity and resistance.

C. Tensile properties of skin

Researches of skin's mechanical properties were begun by Guillaume Dupuytren in 1831 with a patient who had stabbed himself over the heart three times [9]. In this context, Karl Langer has shown in the nineteenth century that mechanical behavior of skin, due to its deeply anisotropic nature, exhibits different properties in each area. [10]. He mapped the natural lines of tension which occur within the skin. The anisotrophic behavior of human skin in different directions has shown by Annaidh et al [11]. At their study, tensile energy varied very large spectrum.

Tensile testing, is an experimenting process, the elongation of the sample and the applied force records by the extensometer. The elongation measurement is used to calculate the strain, *s*, using the following equation;

$$s = \Delta L/L_0 \qquad (7)$$

The force measurement is used to calculate the stress, σ, using the following equation:

$$\sigma = F/S \qquad (8)$$

F= is the tensile force
S= is the nominal cross-section of the specimen

Skin represents an extremely complex structure, because of this reason the mechanical characteristics of the skin are extremely complex and have not been satisfactorily simulated by conventional engineering models. However, it can be said that the most accepted model is the hyper elastic model of Ogden [12].

Young's modulus is a ratio which is the mechanical property that measures the stiffness of a solid material. By calculating or measuring Young's modulus researcher can understand the border of the elastic deformation. Yield strength is the point on a stress–strain curve that indicates the limit of elastic behavior and the beginning of plastic behavior. After this point material begins to deform plastically.(*figure 5*)

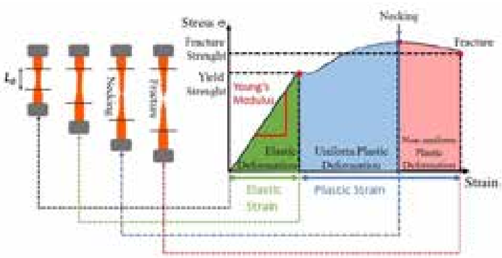

Figure 5: Tensile test result illustration: Stress-Strain Curve

Yielding means the start of the breaking of skin fibers and fiber bounds. Once the yield point is passed, some fraction of the deformation will be permanent and irreversible. The border of the physiological level cold be figure out by the Researcher.

II. Material And Methods

A. Mechanical design of device

Extensometers according to the general power transmission types are manufactured by two types: hydraulic powered and electromagnetically powered machines. In our desing, we preferred electromagnetically powered with a 100:1 gear head Stepping Motor. In this way, we have able to apply high precision tensile stress to the sample. Motion is transmitted to an identical lead-screw with the differential gear set. Thus, the stepper motor one step vise provided 8/6000 mm or sliding movement of grippers. To ensure precise and smooth movement, precision linear bearings and millings were placed on both sides of the screws (*figure 6*).

B. Electronical design of device

Mostly extensometers basically consist of the following electronic parts; force transducer that measures the force applied to the sample, position meter that measuring the amount of elongation, a process-monitoring camera, the control unit controlling the operation and the computer on

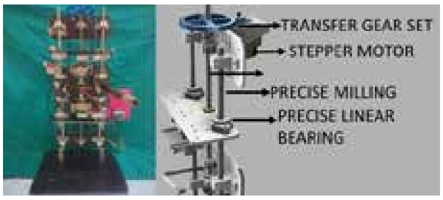

Figure 6: Mechanical parts of design

which the information is created. In addition to the standard components of the existing extensometers, we also added the load cell number to two, and the components we added for

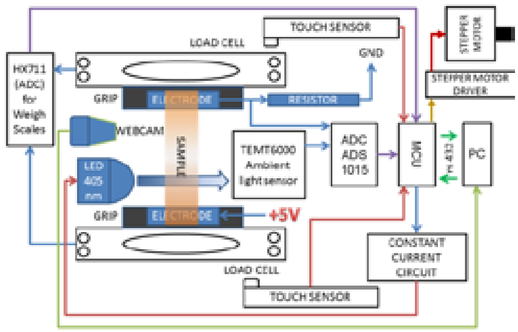

Figure 7: Electronic components diagram

measuring the resistance and the resistance were Ambient Light Sensor, led, constant current drive circuit and a simple resistor brige, and a ADC to convert analog information to digital (*figure 7*).

C. Sampling of biomaterial

Experimentally tested with dead chicken skin on the platform. The samples A3, B3, A2, B2, A1, B1 were tested respectively. Thickness of samples were measured with digital caliper and noted (*figure 8*).

Figure 8: Sampling and naming biomaterial.

III. Results

Force strain-curve has variations with the thickness of skin. Following (*figure 9*) chart shows these variations. Data collection ended with skin tearing.

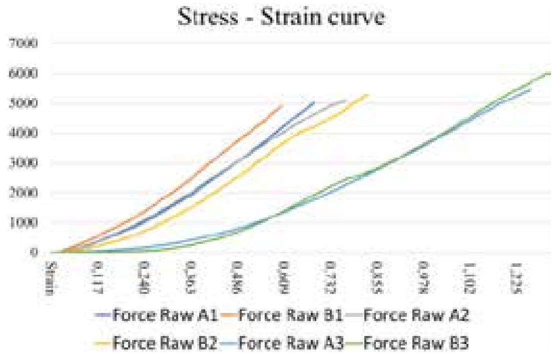

Figure 9: Force- strain curve with raw data

Kirchhoff's Voltage Law or KVL, states that "in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop". On based this law, we measured the potential difference on the reference resistor. The established circuit is shown by *figure 10*. The equation for the skin resistance is given below(9-11).

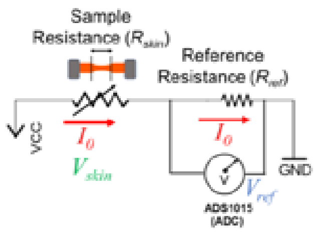

Figure 10: Electronic components diagram

$$V_{skin} = V_{Vcc} - V_{res} \quad (9)$$

$$I_0 = V_{res} / R_{ref} \quad (10)$$

$$R_{skin} = V_{skin} \ x \ I_0 \quad (11)$$

Resistance-Strain curve was drawn with next diagram (*figure 11*). Light transmittance is another data what we collected by the device in the study. Light transmittance evolved with strain is shown by following diagram (*figure 12*).

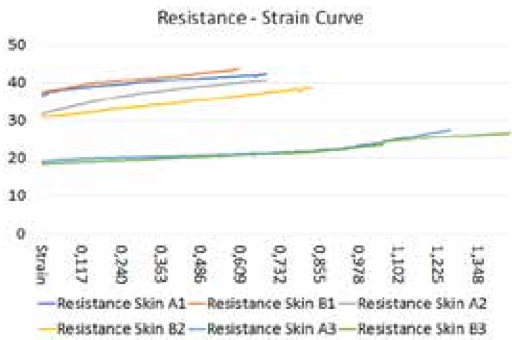

Figure 11: Resistance(kΩ) - strain curve

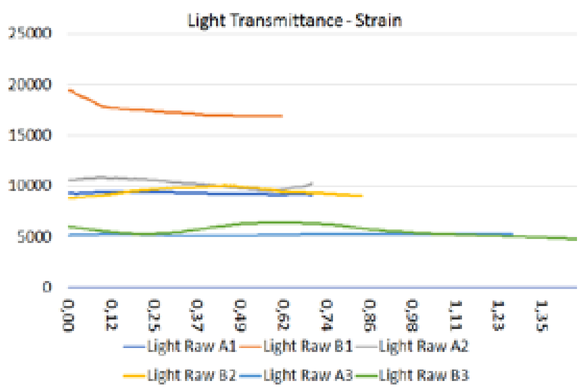

Figure 12: Light Transmittance (raw) - strain curve

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