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Viscoelasticity measurement of skin in vivo by rheometer

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Materials

ABSTRACT

Purpose: The pressure sore is a trouble by the mechanical loading. As for this, the stress concentration occurs to the skin surface, and, next, sphacelation is meant by the skin. However, there is a case where the pressure sore is not improved even if the stress is removed. For this case, defective fixation of the skin is more remarkable than the general person. In this research, the appraisal method was quantitatively proposed for the soundness of the skin.

Design/methodology/approach: This paper proposed the model of the mechanism where the skin received the shear stress and the pressure sore was generated.To verify this model experimenting, it examined it in pathology.

Findings: The experimental results showed that first of all, to measure the viscoelastic property of the skin with in vivo, the measuring instrument using the rheometer was developed. Next, it made comparative study with the state of pathology of the pressure sore with this measuring instrument. As a result, it was able to be suggested that defective fixation of the skin decide the form of the pressure sore. In addition, it has understood though the state of the therapeutic approach and the prognosis can be evaluated.

Research limitations/implications: In this research, the skin was measured using the probe and the rheometer which devised the stage. At this time, the datum point of the rheometer measured by assuming in the bone upper part.

Practical implications: This paper cleared that it is influence of the measurement place of a skin viscoelasticity value. As a result, it was suggested that the preventive care of the bedsore becomes possible.

Originality/value: The objective of this research project was to develop the skin appraisal method was quantitatively proposed.

Keywords: Non-destructive testing; Biomaterials; Viscoelasticity; Skin; In vivo; Rheometer; Bed sore

1. Introduction

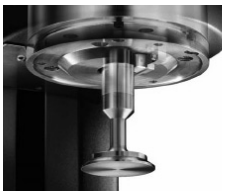
The engineering of human tissue represents a major technique in clinical medicine [1-3]. Material evaluation of skin is important as preventive medicine. Decubitus originates in pressure and the rub [4-7]. However, shearing in the skin has exerted the influences on the sore pressures most [8-17]. This paper examines one demand of crucial importance, namely the real time in vivo monitoring of the shearing characteristics skin tissue. Rheometer is a technology developed to measure viscoelasticity of solid and liquid. To measure viscoelasticity of the skin in the noninvasive with this device, we remodeled it. It is ideal for the continuous monitoring of tissues in vivo.

2. Experimental device and experimental method

Fig.1 shows the rheometer used by this research. This measuring instrument machine is AR550 made by TA Instruments, and the angular velocity is 100rad/s, and the situs perversus resolution ability is 0.62 micro rad. Fig.1 (a) is the whole rheometer figure. The lower measurement stage is being fixed. And modification is given to the top probe shown in Fig.2 (b). As a result, stress distribution and frequency distribution can perform viscoelasticity measurement.

The photograph under measurement is shown in Fig.2. The photograph of Fig.2 is in the measurement status of the ramus-palmaris-nervi-ulnaris palmar upper part. It was performed as follows so that the disk of a probe and operation of the skin might be in agreement. A probe disk and the skin attached the fixed jig on the measurement stage so that it might become isofacies. In this research, it measured by the stress distribution and displacement distribution which agitation of the skin tends to measure. What must be careful of tends to receive the position of the bone part under the skin, and the influence of form in viscoelasticity measurement of the skin.

(a) General view



(b) Probe

Fig. 1. Viscoelasticity determination equipment

In this experiment, there is distance from an outer cover to a bone part, and near the forearm part center where which indirect operation part cannot be found on the outskirts, and the stable agitation is obtained was made into the measurement part. An experimental condition is shown in Table 1.

3. Experimental result and consideration

3.1. Relation between skin agitation and phase difference

The viscoelasticity determination result of the forearm palmar part of 24 years old, 36 years old, and a 50 years old male is shown in Fig.3. M24-01 is 24 years old, M36-01 is 36 years old, and M50-03 is 50 years old. Moreover, all measurement persons are male. As for the phase angle delta, a big change was not seen although storage modulus G' and loss modulus G" changed with measurement conditions, such as a measured region and forcing power, a lot during measurement. Here, when its attention is paid to delta, in M50-03, it understands that agitation of the skin becomes large and it is impossible to follow to displacement near the amplitude stress 10KPa.

However, in M36-01 and M24-01, most agitation was not seen (20KPa or more), but was understood that displacement of a probe and the skin is almost the same. Moreover, change was not accepted in the range until a phase progresses with the increase in stress in all the measurement results of whose were about 13 degrees in 5KPa or less, however M50-03 and a phase angle results in 20KPa in M36-01 and M24-01.

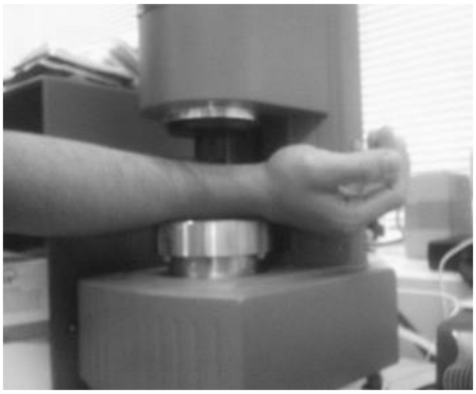


Fig. 2. Photograph at viscoelasticity determination of forearm part

Table 1.
Experimental method

Dispersion type	Dispersion	Forcing power	Frequency
Stress	0 to 40 KPa	3.0 N	10 Hz
Frequency	$10^{-3 \text{ to } 0}$ rad		

3.2. Part characteristic of a skin viscoelasticity characteristic value

The viscoelasticity measurement result of a 34 years-old male's forearm back side part is shown in Fig.4. M34-P01 to P03 expresses the measured segment. The wrist side is P01, the elbow side is P03, and these middle is set to P02. The position of the measurement segment of P01 to P03 is shown in Fig.5. In the case of measurement of P01. Measured value is not stabilized near a joint part. Therefore, in P01, near the central part in which measured value is stabilized was measured, and in P03 which is a joint part like P01, it was the measured value stabilized on the whole elbow.

If Tan (δ) of Fig.4 is observed, Tan (δ) will increase most to the increase in displacement of the wrist side. Next, the elbow part was large and the intermediate part was the lowest value. G' and the difference over displacement of G" did not almost have the elastic modulus of an intermediate part, and they were about 100 KPa(s) (G') and 250KPa (G"). However, the elbow part had the large agitation to displacement, and G' decreased rapidly with the increase in displacement. It seems that this is because flexibility changes a lot with the distance from the bone part used as the base of the skin, or composition.

3.3. Relation between a viscoelasticity observed value and the skin

From the above result, it seems by measurement by stress distribution that the phase difference delta is what can show the correspondence to the external force of the skin, i.e., the degree of agitation of skin structure. This understands that the result of M50-03 is going up rapidly from about 5 KPa, and the viscous clause is dominant so that clearly from Fig.3.

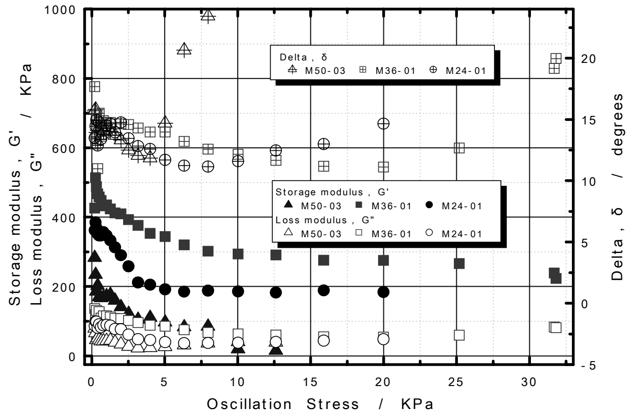


Fig. 3. Viscoelasticity determination result of male forearm part: M50-03 is 50 years old, male, M36-01 is 36 years old, male and M24-01 is 24years old, male. Black-lacquered symbol are strage modulus G'. White symbol are loss modulus G". Cross overlapped symbol are phase difference (Delta) δ

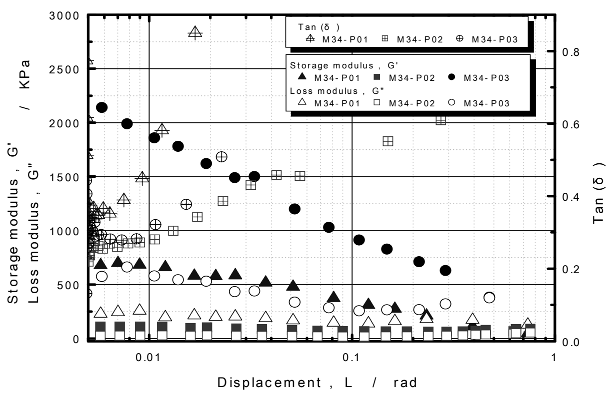


Fig. 4. Viscoelasticity determination result of part dependability: M50-03 is 50 years old, male, M36-01 is 36 years old, male and M24-01 is 24years old, male. Black-lacquered symbol are strage modulus G'. White symbol are loss modulus G". Cross overlapped symbol are phase difference (Delta) δ

On the other hand, it is possible that M36-01 and M24-01 are understood that an elastic clause is dominant, and express the relation of agitation between external force and the skin clearly since change is not seen to 20KPa. Next, in measurement by displacement distribution, it seems that it is what can see a move of the whole skin structure from a bone part to the skin. This is considered to express the degree of movement of the whole organization so that viscoelasticity measurement of a polymer material etc. may also be the same. These results have suggested the possibility of the soundness evaluation of the skin considered to become a cause of generating of the bedsore by viscoelasticity measurement of the skin.

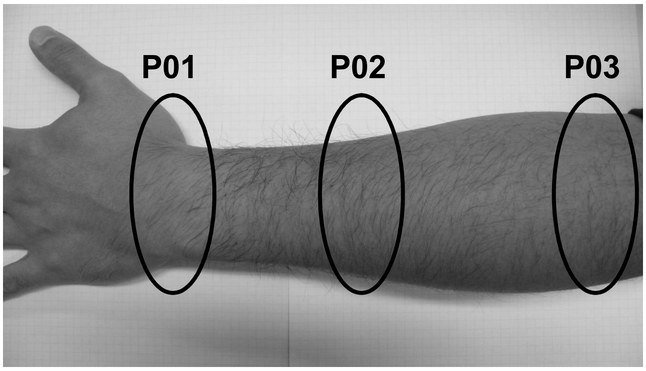


Fig. 5. Position of the measurement segment of P01 to P03: P01 is wrist part. A measurement part is the central part without a joint; P02 is upper arm part, It does not have the influence by a measurement part; P03 is elbow part, It does not have the influence by a measurement part

4. Conclusions

The following things became clear as a result of doing research by viscoelasticity measurement of the skin.

1. Stress distribution measurement showed that agitation of skin structure could be evaluated.
2. Displacement distribution measurement showed that the movement state of the whole skin structure could be evaluated.
3. By viscoelasticity measurement of the skin, it has suggested that soundness evaluation could be performed.

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