Ex-Vivo Cow Skin Viscoelastic Effect for Tribological Aspects in Endoprosthesis

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Abstract: Abstract: The viscoelastic behavior of ex-vivo cow skin was experimentally studied by applied load from different indenter types (circle, square and triangle, all types have the same area) for different times (10 sec, 30 sec, and 60 sec). The viscoelastic tests were carried out using a UMT series (UMT-II, CETR Corporation). The experimental results collected at different operating conditions showed that the cow skin has a higher reaction against the triangle indenter compared to the other shapes. Whereas the hysteresis of cow skin was lower at low applied load time and it's increased when the time increased.

Keywords: Ex-vivo cow skin, viscoelastic, friction.

1. Introduction

According to the latest reports of much international organization, there is a huge number of amputee persons all over the world due to many factors like diabetes, landmines, etc. besides to the overpopulation, all these reasons makes a large demand on prosthetic limbs and consequently too many associated medical problems are rises up for example ulcer formation, trauma, and keratinization in the stump human skin as a result of direct contact between the residual skin and the internal layer of the socket, so that encourage researchers to deeply start investigation in such effective and humanitarian topic, here and below a detailed literature review with miscellaneous related aspects.
Li W. et al [1] used a piece of rabbit skin as a testing material with the aid of the UMT- II tribometer at a sampling rate of 20 KHz, so in order to study healing process, two phenomena have been examined, they are skin self-rehabilitation and self-adaptation to friction trauma where a simple simulation process considered to simulate rubbing conditions between rabbit skin and prosthetic socket. Final results indicate the formation of the so-called keratinization on the direct contact region between the two mating surfaces after several alternations of the trauma which leads to the coefficient of friction decrement, this is, of course, happening because of a viscoelastic feature of such skin.
[2] Żak M. et al started studying sectional layers of the domestic pig skin, then examining the most effective mechanical properties for such particular skin taking into account the random direction of the collagen fibres. Many uniaxial tensile tests were done to find out the expected essential features with respect to its sectional structure. Concluding facts indicated that, there were no considerable differences in the acquired values of the maximum tensile strength and the associated modulus of elasticity (Young's modulus).
Khatyr F. et al [3] suggested a comprehensive single axis tensile test for a viscoelastic material by studying creep and relaxation behavior of in-vivo human skin. The nominated area is forearm skin for 63 volunteers with different ages where the skin has been considered as an orthotropic material. The final conclusion was that the gained results based on the viscoelastic model are independent, on the type of the applied load or it is true to say that principal direction of experiments varies from one

volunteer to another one, means that Young modulus could be considered as a function for the dermatologist and skin care centres.
Kussay et al [4] suggested a mathematical model used for measuring a hysteresis component of friction between human skin which obeys Voight mechanical model and a rigid sphere taking into account different friction parameters such as the applied load, probe velocity, the strength of the interface between skin and the artificial material. The deformation (hysteresis) component of the skin friction model is developed by using the Mathcad software. The gained numerical results showed that the adhesive component of the skin friction is greater than the hysteresis component at all operating conditions.
[5] Li W. et al studied improvement of friction conditions between the prosthesis and the stump in case of below knee amputation, where maximum direct contact happened due to load transfer depending on the total weight of the amputee person which in turn causes many dermatological problems, so two phenomena have been studied in this paper, they are skin self-rehabilitation and self-adaptation to friction trauma based on specific friction testing and viscoelastic properties of human skin in assistance with UMT-II tribometer machine. Final investigations showed the formation of keratinization in the two mating surfaces region and consequently ascending variation in coefficient of friction happening.
Soldatenkov I. [6] calculated the dominated component (deformation) component of the friction force for a viscoelastic substrate based on energy approach. A modified punch has been used to measure friction force with different surface finishing and geometry conditions, final results proved that friction conditions is a function of punch smoothness, or friction forces increased as the punch surface is less smooth and vice-versa taking into account tip geometry. Chisiu G. et al [7] a technique was used by a device (UMT 2 tribometer (CETR, Campbell, CA, USA)) to study the behavior of UHMWPE and to verify the analytical results of the Zener model.
Cheng L. et al [8] has selected a three-element viscoelastic material (polymer) which is named Kelvin-Voight mechanical model in his theoretical research to study indentation effect by employing an axisymmetric flat ended indenter and two types of tests were conducted including flat punch creep test and load relaxation test. The attained facts proved that a reasonable quantitative method for evaluating viscoelastic and instantaneous elastic features from experimental expectations, in addition, this proposed solution could be applied to indentation process on the two cases bulk polymers and polymer coating based on the acceptable ratio of the employed punch radius to the coating thickness.
Lyubicheva A. et al [9] employed a pin on disk wear rig to investigate tribological properties of viscoelastic materials, where the analytical model of direct contact between indenter with a spherical tip in touch with rotating disk has been used. The main objective of this work is to examine mechanical (viscoelastic) properties of cow skin in order to create new trends in using such available skin in the prosthetic industries to ensure comfortable direct contact conditions between human skin and prosthetic socket for both upper and lower limbs.

2. Materials and Methods

In order to conduct the experimental part of this paper a well-known rig has been used named UMT-II Tribometer, which has many excellent facilities in this topic, so mechanical properties and viscoelastic characteristics of cow skin are measured according to the following procedure:
A fresh specimen of bull ox aged about one-year cow skin is prepared with the following dimensions (50 x 45 x 3.5) mm where a sterile water is used to wash this tissue without any chemical reactions and shaved well in one direction as shown in figure (1).
The other requirement for this particular test is preparing a three different in shape geometrical tips of indenter (circular, rectangular, triangular) cross-section, manufactured from commercial brass with the equally cross-sectional area of about 16 mm^2, as indicated in the figure (2) below.
The UMT-II Tribometer device used to calculate the mechanical properties of the skin (see figure 3).The tribometer includes a part zoom from contact the tip with the cow skin accordingly, clarifies in detail how to fix this piece of cow skin on the platform of the employed rig, the first step was fixing the skin without any tension or extension, after that starting with the circular stylus fitted on the upper

jaw followed by the other two styluses. Starting with the first moment of touching between the stylus and the skin to consider this first touching point as a reference i. e. zero load point, then starting with a gradual load to reach 1 mm depth in the skin within three different time duration initiating with (10, 30, and 60) seconds. The desired goal is to find out the induced mechanical reaction with all above-mentioned cases taking into account the three geometric tips.

Figure 1. Image of the utilized skin.

Figure 2. The utilized tips of indenter: (a) Circle; (b) Square; (c) Triangle.

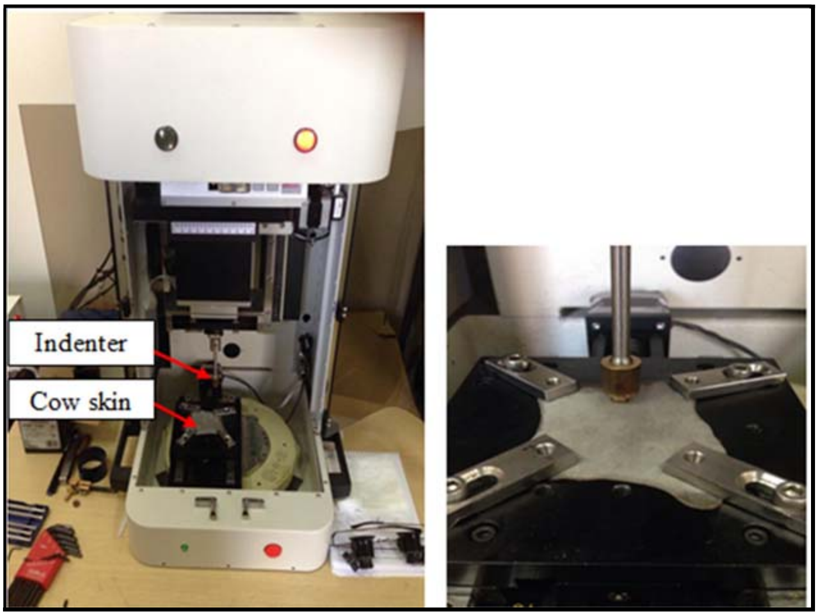
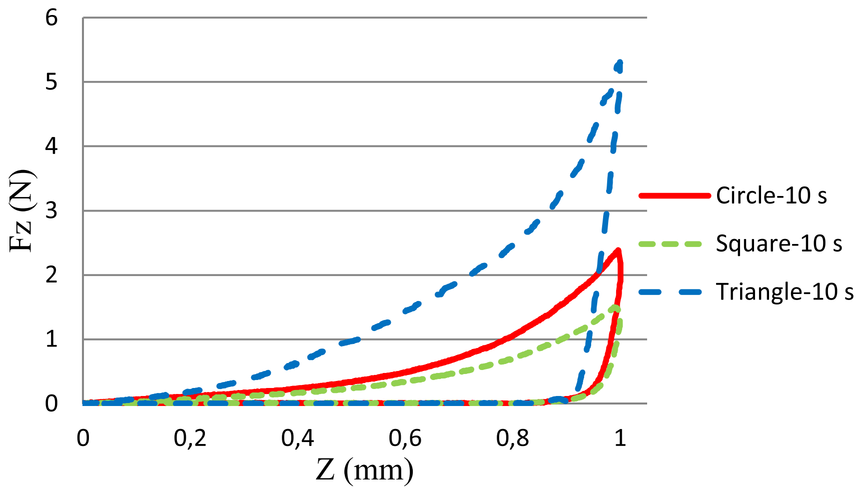


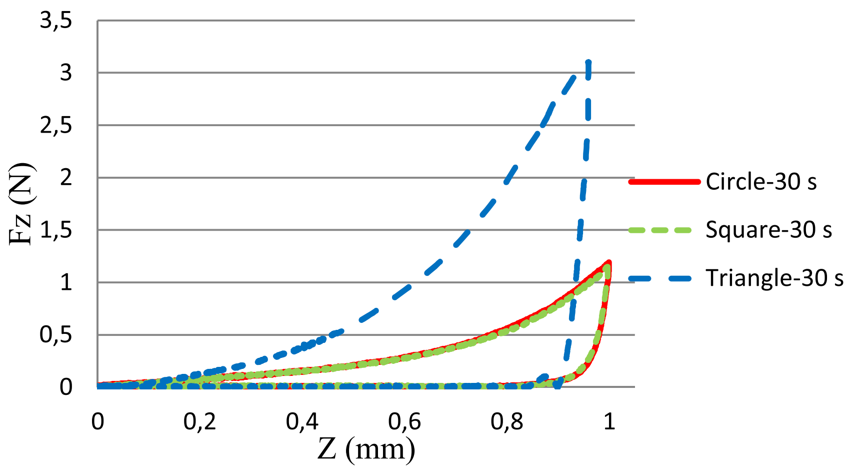
Figure 3. Image of the test device during the experiment explaining the contact with the skin

3. Results and Discussion

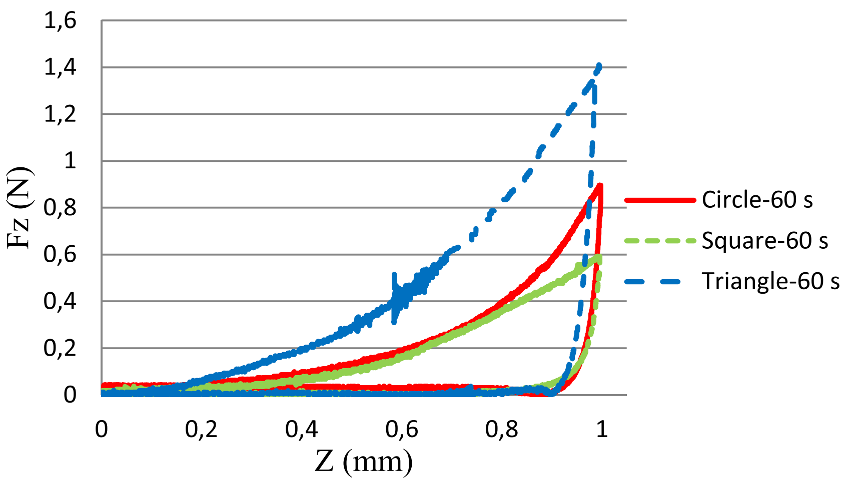
Based on the steps described in the previous section, the results obtained from different geometric shapes over periods of time (10, 30, 60) seconds respectively. The variation of normal force with respect to indenter deep given in figures 4a, 4b, and 4c. The results were obtained from different indenter shapes (circle, square and triangle), the load was applied on the cow skin for time (10, 30, and 60) seconds, separated. As shown in these figures, the cow skin reaction reduced when the applied load time increased. The explanation of this behavior is due to the viscoelastic phenomena of the skin. The maximum cow skin reaction against applied load was when used the triangle shape, whereas the lowest reaction register when used square shape at all operating conditions. The normal force reaction of cow skin against the triangle shape was equal to 5.25 N, 3.1N and 1.4 N, for circle shape equal to 2.4N, 1.2N and 0.9N, for square equal to 1.5N, 1.1N and 0.6N at applied load time 10, 30, and 60 seconds respectively.



(a)



(b)



(c)

Figure 4. Variations of the cow skin reaction respect with depth

The hysteresis of cow skin was determined by using below equations:

$$\alpha_h = \frac{A}{Area\max} \tag{1}$$

$$A = (Z_{i+1} - Z_i).(Fz_{i+1} - Fz_i) \tag{2}$$

$$Area\max = \frac{1}{2}(Z_{\max}.F_{\max}) \tag{3}$$

where: α_h: hysteresis parameter [%], A: area of the curve [mm^2], Fz: normal force reaction (N), Z: depth (mm)

The hysteresis of cow skin when applied the load from three different shapes with respect to applied time shown in figure 5. The hysteresis of cow skin was lower at low applied load time and it's increased when the time increased. The lowest hysteresis of cow skin was with the triangle shape, the explanation of this behavior due to the pressure generated from the edges or sides sharp angles resulting in an increase the skin reaction.

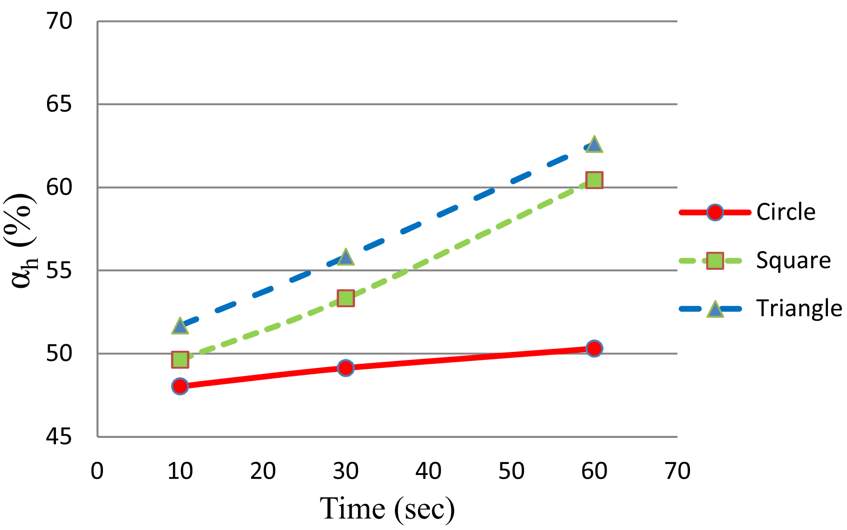


Figure 5. Variations of hysteresis parameter respect with depth

The same procedure above was repeated at the same operating conditions except for the time, the load was applied for 60 seconds, and then left the load for 60 seconds on the cow skin and then removed the load slowly for 60 seconds. The results of this test shown in figure 6. As shown in this figure that the cow skin reaction was significantly lower against the load applied to all tip shapes of the indenter. Again, the maximum cow skin reaction against applied load when used the triangle shape and equal to 6.2N, whereas the lowest reaction was equal to 1.6 N register when used square shape at all operating conditions. The variations of cow skin reaction with respect to time when applied the load from different tip shapes of indenter shown in figure 7. It's clearly shown from this figure that the cow skin reaction becomes approximately zero value after 120 second from the load applied; this may be due to the skin creep.

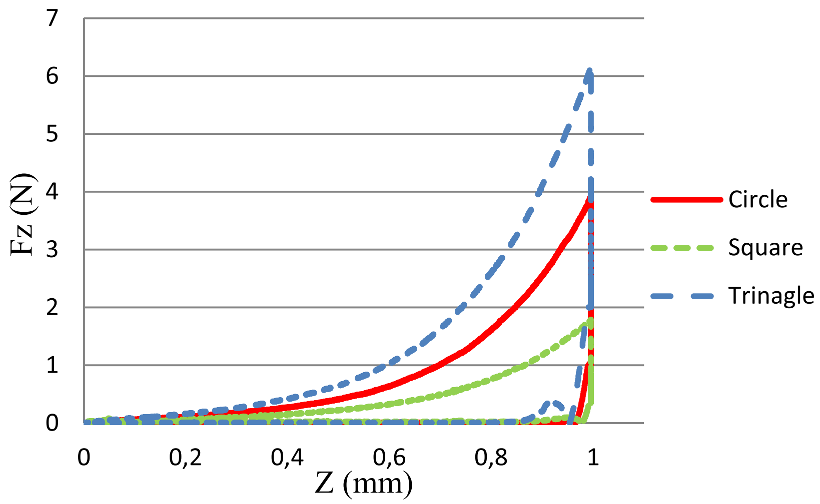


Figure 6. Variations of the cow skin reaction respect with depth in the case stay 60 second

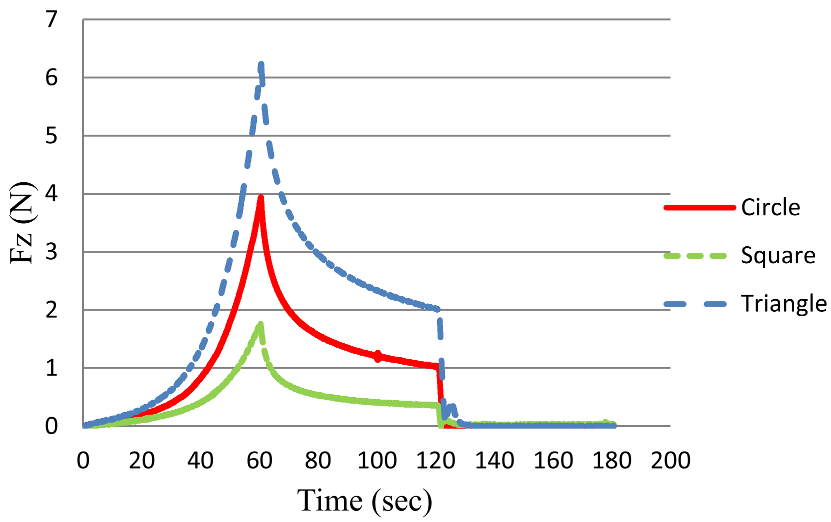


Figure 7. Variations of the cow skin reaction respect with time in the case stay 60 second

4. Conclusion

In the current study, the viscoelastic behavior of ex-vivo cow skin was experimentally studied by applied load from different tips of indenter (circle, square and triangle, all types have the same area) for different times (10 sec, 30 sec, and 60 sec).
The important findings are summarized:
• The cow skin reaction reduced when the applied load time increased. The maximum cow skin reaction against applied load was when used the triangle shape, whereas the lowest reaction register when used square shape at all operating conditions.
• The hysteresis of cow skin was lower at low applied load time and it's increased when the time increased, the lowest hysteresis of cow skin was registered when used triangle shape compared to other shapes.
• The cow skin reaction was significantly lower against the load applied to all tip shapes when the load still 60 seconds on the skin. Again, the maximum reaction was 6.2N against a load applied when used

the triangle shape, whereas the lowest reaction was equal to 1.6 N register when used circle shape. Equations and mathematics

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