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An Innovative Approach of Examining Post-Mortem Skin Changes from a Mechanical Perspective, Stiffness based Novel Analysis

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Abstract: ***Forensic medicine is an important branch of forensic sciences. The need of timing determination should be based on sound comparable reproducible measurement, namely parametric approach. For the first time we reported a new method to measure postmortem changes and correlate them to death time. Our results showed clearly how the skin is changing after death. These changes will continue n predetermined controlled fashion until total decomposition of the body occurs. We conclude that mechanical properties of the skin correlating with the time passed from time of death could aid in death time determination.***

Keywords: Forensic medicine, skin biomechanics, postmortem changes. Strain, displacement.

1. Introduction

Postmortem skin changes are very complex process (1). The mechanical properties of the skin are very difficult to be demonstrated and it is very difficult to be discerned. It had multiple phases and staged damage patterns. (2)

It is occurring as well as all other pathological processes in very complex predefined processes. growth, pathological processes, such as scleroderma, as well as postmortem changes are all predefined process. (3) These changes could be tracked parametrically (4). These changes occur at many levels, and the molecular and cellular level will also have an effect on the total mechanical properties of the skin. The total mechanical properties are derived from the whole elements of the tissues (cellular and extracellular matrix) (5). One of the most important features that needed to be used is to be non-destructive, so that the examined sample will remain undamaged.

Our approach to understanding the mechanical properties of the skin postmortem include mechanical evaluation of the skin in a way that give us numbers and charts that is comprehensible by non-engineering audience (6). We had provided an introductory model and 2 criteria of evaluation had been used.

- Displacement
- strain

Introductory model is an experiment where a single model had been studied that provides an insight into algorithm for studying larger sample. (7)

2. Methods

A young rabbit had been selected and euthanized according to the protocol mentioned (8). Prior to euthanasia, the animal analysis of the skin had been done. As the experiment was to demonstrate the changes postmortem, we had not applied any preservative over the animal. In this paper we want to demonstrate a new algorithm to reveal the postmortem changes of the skin.

The animal had been laid on his side and fixed to the underlying board using cyanoacrylate glue.

A linear stage was used to provide traction with constant direction across all traction trials. We think that the 6 hours is the most critical period that the changes are clear and could be easily captured. With longer time passed the changes will be more subtle to be captured (4). We had done multiple tractions, 12 times, after euthanizing the animal. The room temperature was about 30 c degrees. Young healthy rabbit had been chosen. The region of the skin to be examined was chosen at the lateral side of the animal and had been trimmed with an electric razor after anesthetizing the animal. The skin area was dotted so that the engineering analysis could be retrieved from the imaged region. Scientific monochromatic sensors with frequency of 120 had been used in the imaging.

The timing was about 30 minutes between each analysis. We followed the postmortem period for 6 hours which we consider the most important period. The timing determination of death is a very crucial process, as if it is registered well could give an approximation of death time which could give a clue in many complex forensic cases. (9)

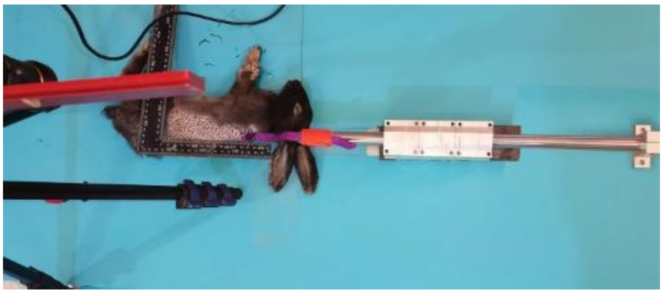

Figure 1: The experiment set up

The displacement and strain are captured at the surface, but the deeper tissues are fixed, at which level the movement is occurring should be determined. (10) U/S and synchrotron radiation microtomography could reveal this dynamicity (11). The changes at different levels should be correlated to the net movement that occurs at the surface.

3. Results

3.1 Physical experiment

We should declare that all our analysis is depending on Reiath`s concept (12) In this research we had only analyzed the pattern of the resultant displacement and strain for the surface and for 10 points we had analyzed displacement, velocity and acceleration. Other mechanical variables could be further analyzed in more detail with more concentration on getting numbers to satisfy the need for statistics.

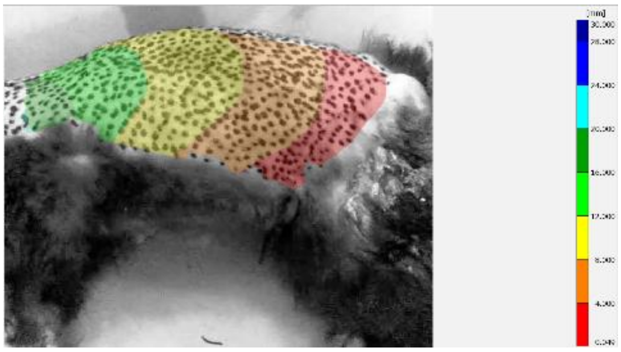

Figure 2: Max displacement premortem (the animal still breathing), this legend of displacement here will be used for all following displacement figures.

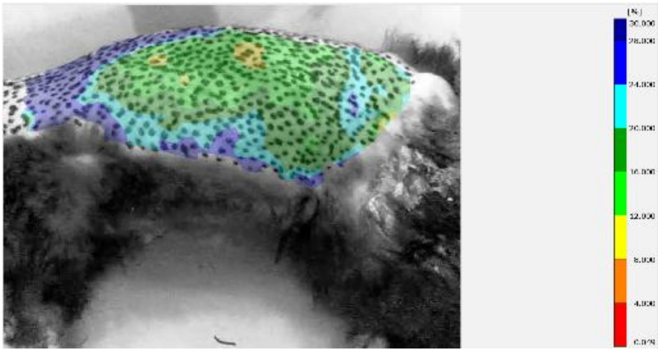

Figure 3: Max strain premortem (the animal still breathing), this legend of strain here will be used for all following strain figures

Examination of the displacement figures across all experiment stages clearly shows the pattern of displacement, where green regions represent the highest displacement, start to fade with passing time (region number could be further customized to reveal more detailed description). Smoother blended transition of the color could be represented but it will produce less interpretationable model than model with segmentalized colors. The strain changes from the start to the end show clearly how the tissues are stretched, and which part of tissues provide the elasticity needed to increase the volume or size of the tissues. These engineering analysis results should be correlated with the histological components of the skin. The strain of the peripheral skin away from the traction axes is clear.

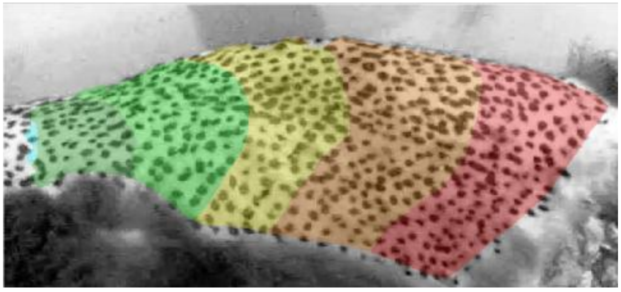

Figure 4: 1st max displacement (immediately after death)

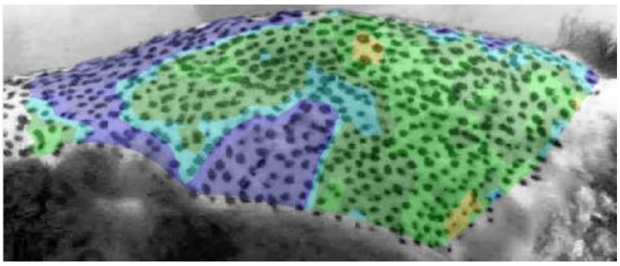

Figure 5: 1st max strain (immediately after death)

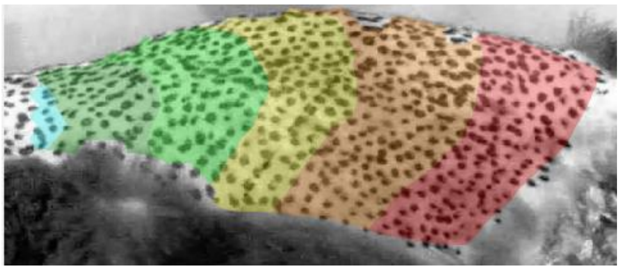

Figure 6: 2nd max displacement

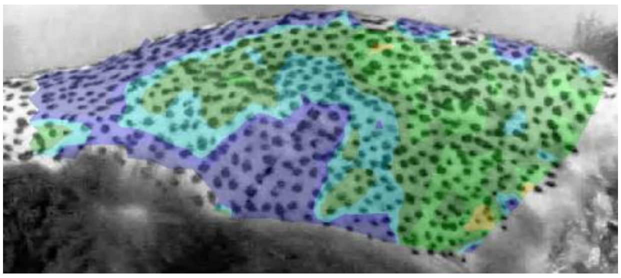

Figure 7: 2nd max strain

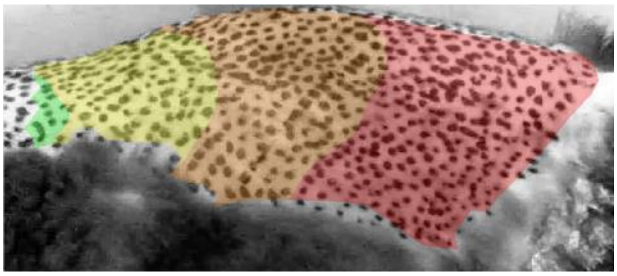

Figure 8: 3rd max displacement

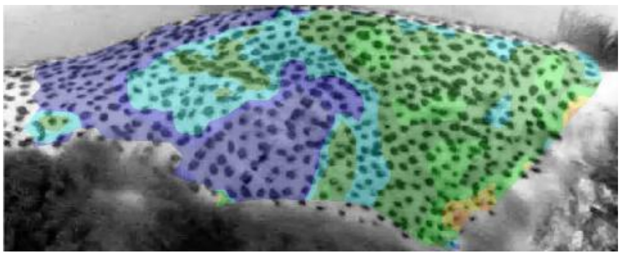

Figure 9: 3rd max strain

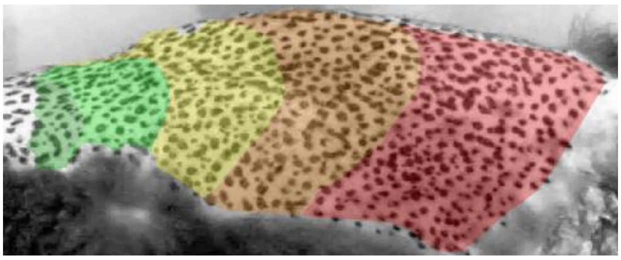

Figure 10: 4th max displacement

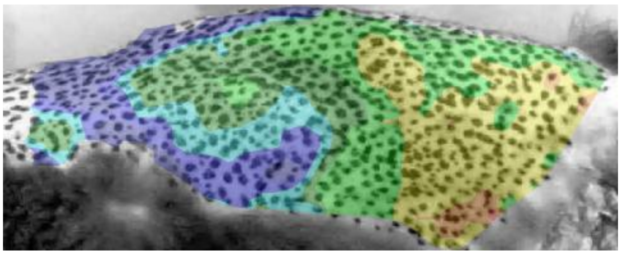

Figure 11: 4th max strain

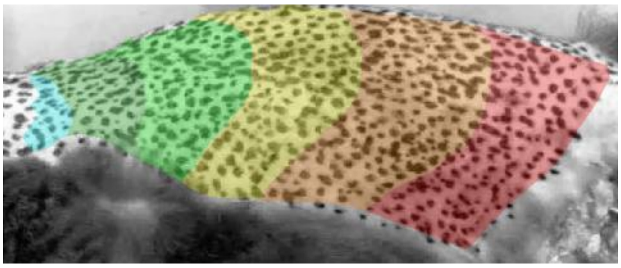

Figure 12: 5th max displacement

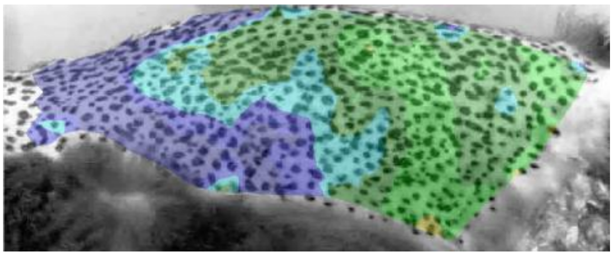

Figure 13: 5th max strain

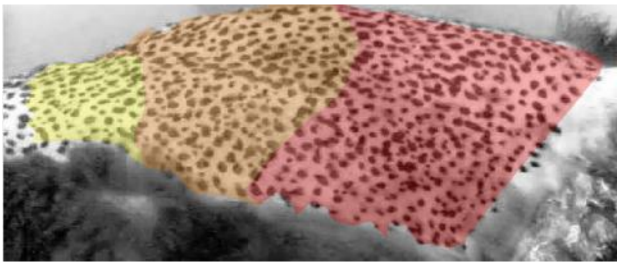

Figure 14: 6th max displacement

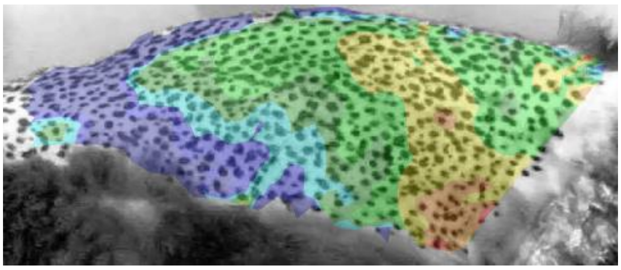

Figure 15: 6th max strain

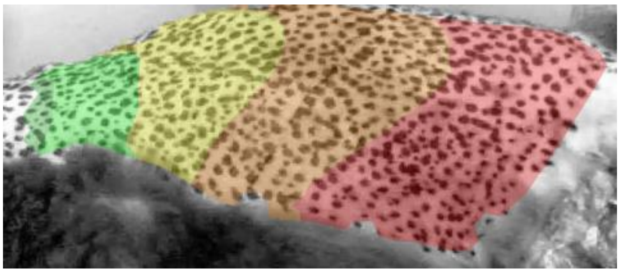

Figure 16: 7th max displacement

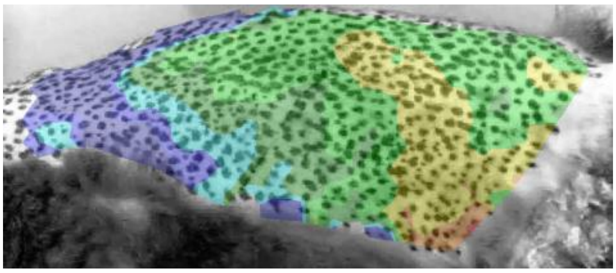

Figure 17: 7th max strain

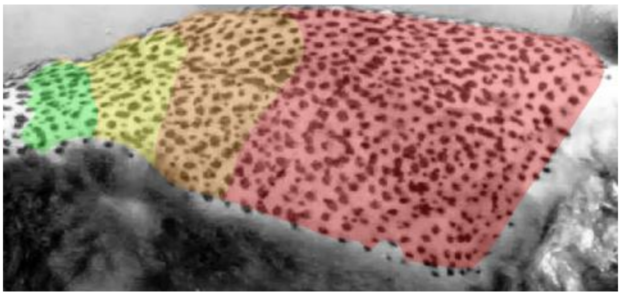

Figure 18: 8th max displacement

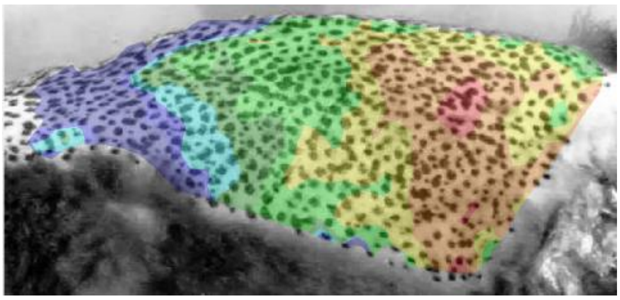

Figure 19: 8th max strain

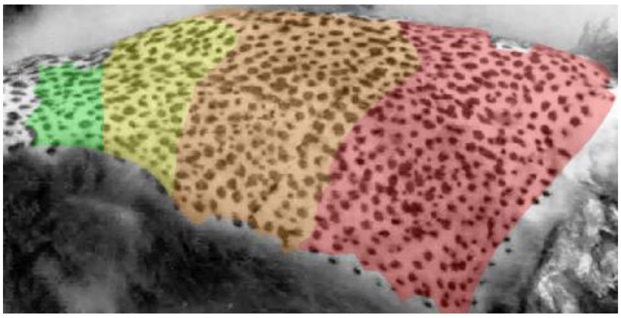

Figure 20: 9th max displacement

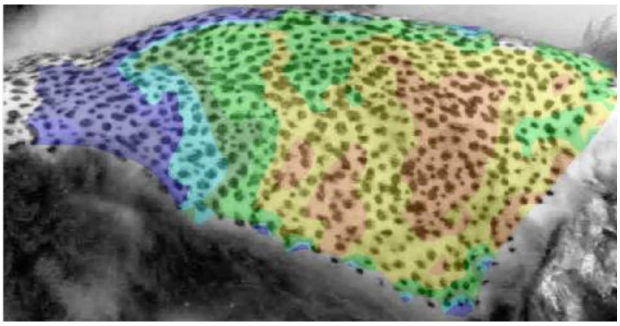

Figure 21: 9th max strain

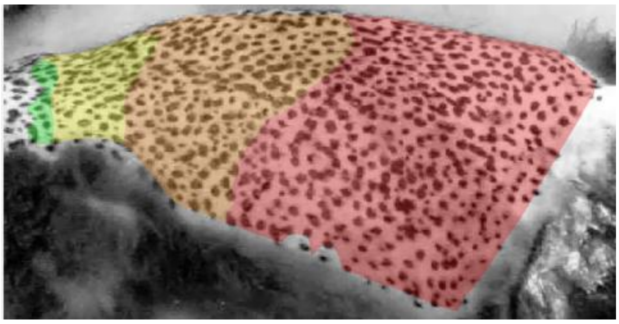

Figure 22: 10th max displacement

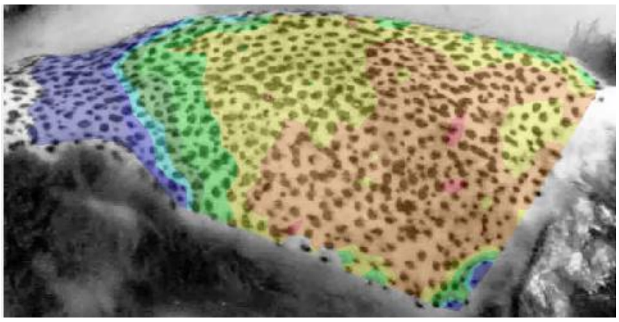

Figure 23: 10th max strain

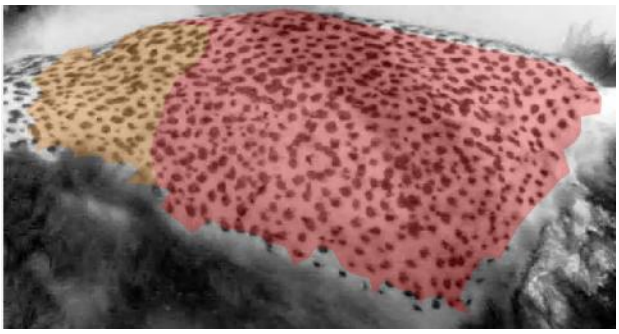

Figure 24: 11th max displacement

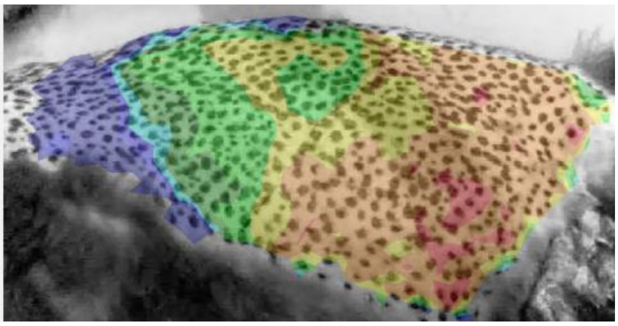

Figure 25: 11th max strain

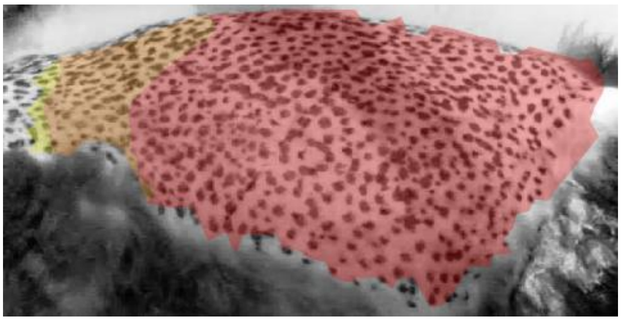

Figure 26: 12th max displacement

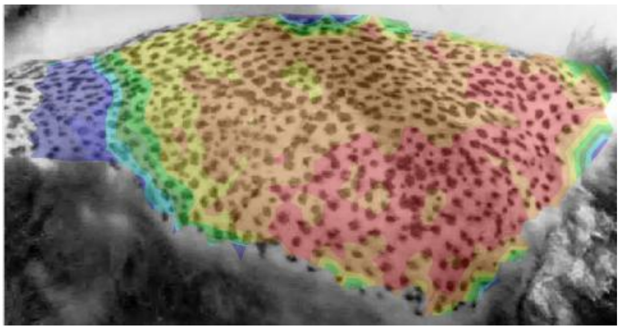

Figure 27: 12th max strain , no peripheral strain as noticed in the start

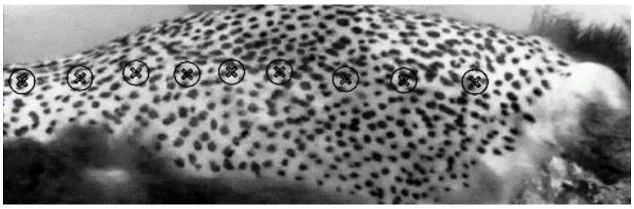

Figure 28: The chosen 10 points

We had chosen roughly 10 points at the long axes of the traction. The next charts are just for the return and the deformation need automated traction, as manual had non uniform traction pace.

These charts had been used to demonstrate the reverse of return; reverse recording method is a very powerful method that makes interpretation of the result easier. The application of traction force has been done manually so that velocities and acceleration are not standardized, while in the case of return we just leave the skin, and it will return to its initial position. The rate of return is much slower in the case where 6 hours have passed. The traction force was applied until we started to move the animal and the traction displacement had not been correlated to the force applied.

The maximum displacement happened after about 6 hours of death was clearly lower than the first time immediately after death.

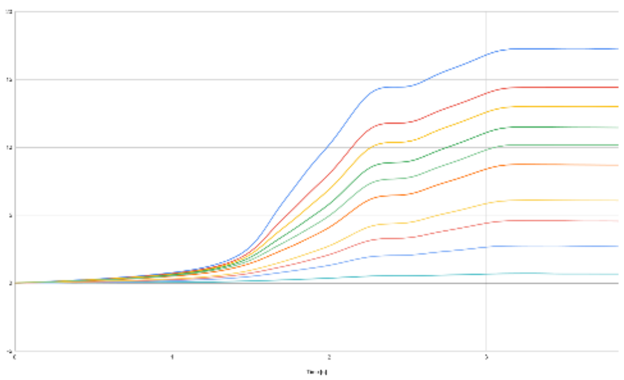

Figure 29: Displacement of the start (mm)

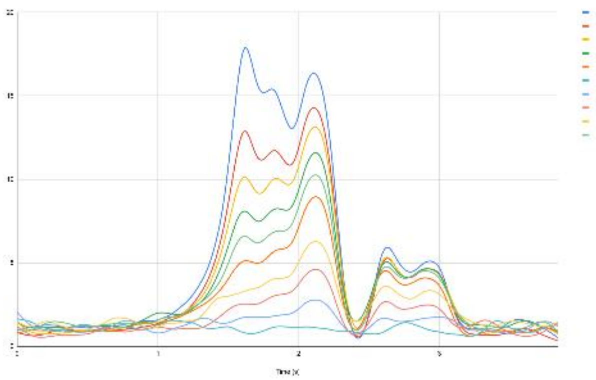

Figure 30: Velocity of the start (mm/s)

Time to return to the pre-traction condition takes longer in the case of the skin after six hours. We have 3 phases of return in the fresh death skin while after 6 hours we have 2 phases. The transition of each point in the case of 6 hours after death is not coincident indicating the need for deeper research.

Velocity in the case of start had more uniform course where elasticity could dominate at that time, after 6 hours we get more non uniformity. We should consider studying different axises at different horizontal levels. The traction forces had certain vectors, but we think that issues had different responses` axises and this is changing with time, anyway it needs deeper exploration.

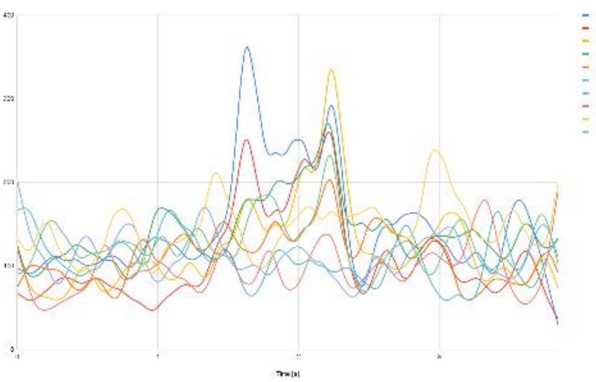

Figure 31: Acceleration of the start (mm/s2)

The tissues' responses are not simple linear events. It is occurring due to multiple interaction from tissues blow (we are analyzing the most superficial part and not the deep part) as well as from adjacent regions: in front, behind and laterals in relation to the long axes of traction. When we tract any region there will be:

- compression in front
- traction and expansion in behind
- shear to the lateral regions

So, the response will depend upon a wide region rather than just the tracted area. Acceleration is a very complex criterion to be interpreted.

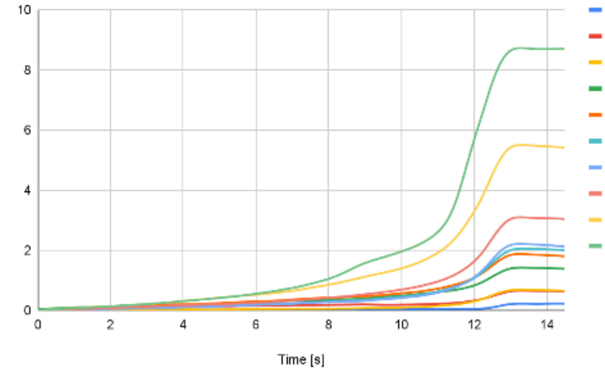

Figure 32: Displacement of the end

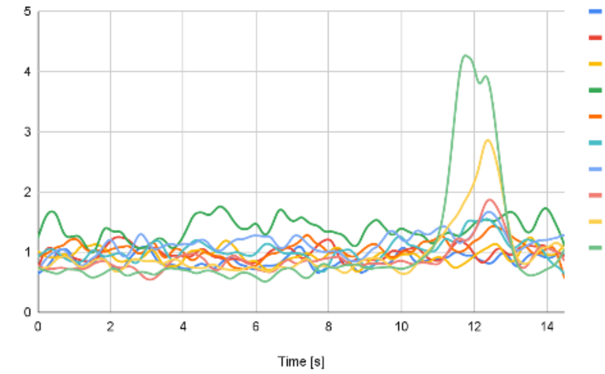

Figure 33: Velocity of the end

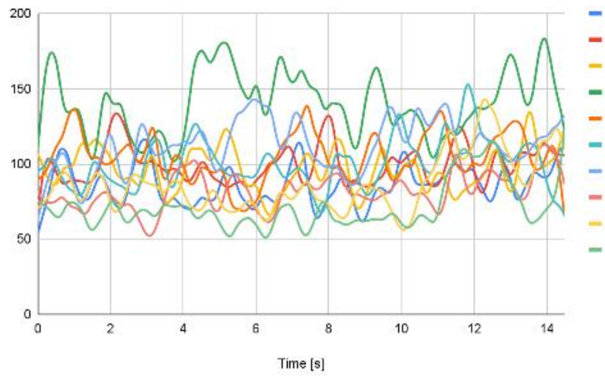

Figure 34: Acceleration of the end

The ratio between different elements is the golden ratios. Yet another golden ratio is in results between skin in different anatomical parts.

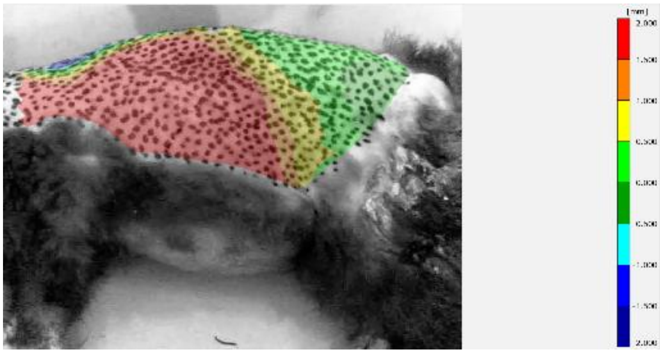

Figure 35: Max Y displacement immediately after death

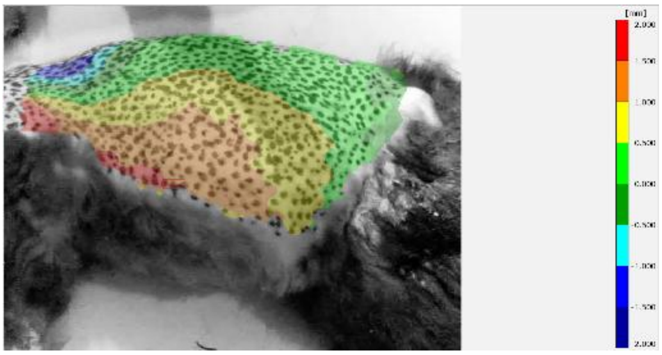

Figure 36: Max Y displacement finally

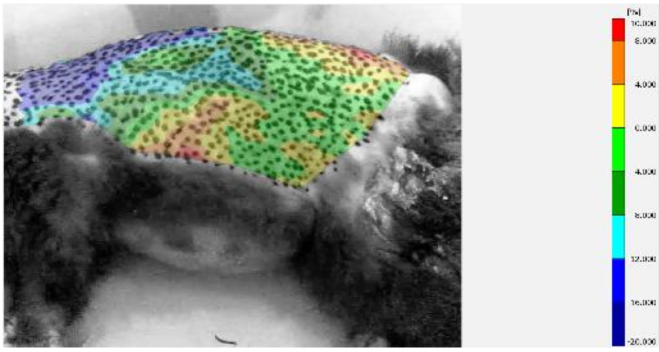

Figure 37: max Y strain immediately after death

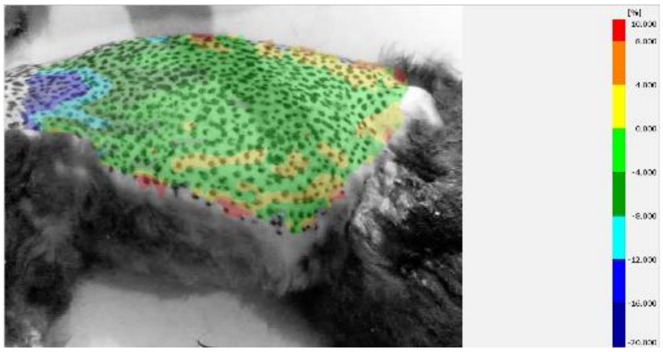

Figure 38: max Y strain finally

Any traction as we said, will exert a certain effect on the adjacent tissues. Y displacement reveal this effect and how the away tissues no on the traction line is behave

3.2 Our CINEMA 4D our work

In many instances when authors of different research deal with mechanical properties of vital tissues, they use finite element analysis packages to produce a simulation of finite models of the well-analyzed biomaterials. We think that it needs an intricate arrangement of the virtual model inside the FEA package and the results are gotten after invasive calculations are done. If any tuning is to be done the calculations must be repeated from the beginning. We suggest using the art of state animation software that has been used for a long time in great simulations of mostly all materials and has been used in medical simulation.

These are the drivers for us to use it:

- It gives instant results after modification of the input parameters.
- Its calculation cost is much more affordable.
- In the specialized FEA packages, the strain or displacement could be demonstrated by direct plotting on the surface of the analyzed geometry while in this model we could get analysis in Using such virtual object with dotted pattern will yield results close to the physical model. This makes us believe that this is the same way that we deal with the tissue samples in the physical lab. According to our knowledge, no one embraces this technology in such analysis before

We share the same conviction that the blood vessels and nerves had little effect on the mechanical properties directly and don't agree about neglecting skin when modeling this assembly of muscle and bone. This pattern was used as a texture for the supposed virtual skin model.

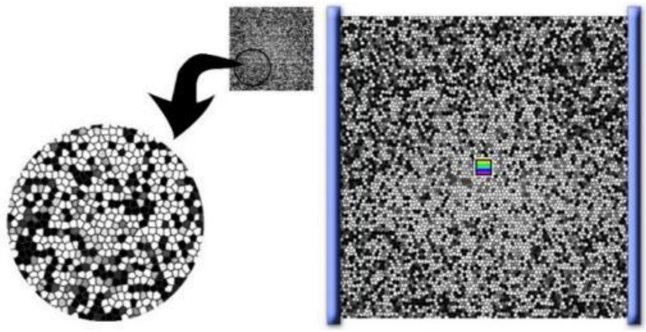

Figure 39: Virtual sin model when deformed by traction of the central square with its pattern.

It is a good pattern and had a good contrast between its elements. The dimensions of the virtual model of skin were 40 * 40 cm. The right and left edges were fixed. A virtual piece of non-deforming material had dimensions of 1*1 cm and was perfectly adhered to the skin.

virtual skin model. Fixed from right and left sides. The central rainbow coated square indicates the traction body. We move the middle object by 1cm to the right and render the resultant deformity. The rendered video footage then analyzed to see the effect of the traction. We had done deformation of the 3 hypothesized model:

- We build a model with what we regard as a normal model with normal laxity.
- We increase the stiffness of this model by increasing values of the rubberiness and some other values that define the properties of the model inside of C4D and regard this model as sclerodermic skin.
- We make a new model with same properties of the first model but we but a constrain to see the effect of constraint on the deformation.

As seen here, the difference of this figure from the previous figure may not be evident, but the major strain in the non-modified skin was the following:

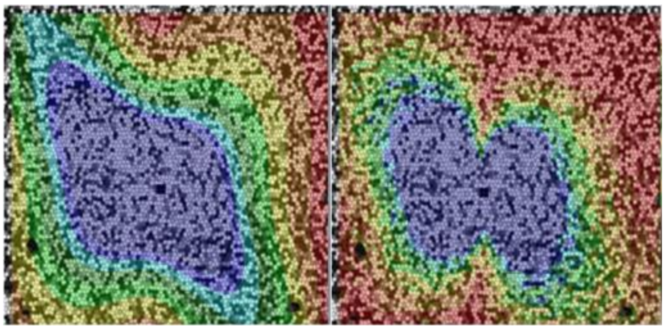

Figure 40: Displacement and strain of the non-modified skin model

Major and minor strain is used as a criterion to test the formability of the metal sheets. We had customized the legend of the plot so that the maximum values of the strain were 0.2 which had the red color and the point with higher strain will have the same color. The value of strain where -0.01 and any point below this value will have the same color, which is deep blue. There are areas where compression happened in the model and this area occurs against the traction. On the other side, stretching happens.

4. Discussion

Strain maximum value had been limited to 30%, as well as maximum displacement was assigned to 30 mm, in the legend had been defined as 30 mm as the upper clipping value. This needs more experiments to settle the best value and get agreed over value. There's still strain and displacement even after the total release of the forces due to the plasticity (13) Blood flow is affecting the mechanical properties of all tissues not just the soft tissues (14) , but we think it also affects hard tissues.

We should admit that the time of death and the subsequent minutes should be studied carefully where the blood flow is stopping.

Death is a critical process that is halting tissues elasticity greatly (15). Note that displacement plot is important, but the strain is also important as it would provide ideas about the relative deformation between different points across the examined field. Although we have not characterized it, we believe that responses of different anatomical regions are also different, and this should be searched carefully (16). It could be done by dismantling the animal limbs. Skin separated from the animal could also be used but it will remove the effect of the environment of the sample environment over it. We should declare that all our analysis is depending on Riadh`s concept.

Displacement should be reviewed simultaneously with strain to reveal the expansion and expansion source. There's still strain and displacement even after the total release of the forces. This is the clue to understand the plasticity in the postmortem changes. And these remaining deformities should be studied carefully. We should admit that the time of death should be studied carefully where the blood flow is stopping. Blood flow affects the mechanical properties of all tissues. In this research we studied only traction.

The studied criteria are the field displacement and strain. In each time we apply traction force, there is a remaining deformity that means a certain amount of yield strain has been reached and passed. This will affect the successive traction trails and their analysis results. This plasticity (at return from traction) is not less in value and importance than deformation as studying plasticity postmortem could be more important than the deformation itself. The stage was manually driven which should be automated to achieve parametric comparison and to correlate this to the return.

The return is the phase that their skin returns to its pre-traction phase. These changes are strain rate dependent which need multiple samples where any yield strain will be applied on virgin tissues. Although decaying start to occur once death had been occurred, decaying by itself is another process that also need further investigation (17)

According to our results the changes have vanished gradually. We should consider that the changes could be possible plastic postmortem, at some levels of mechanical properties of the skin.

5. Conclusion

Engineering approach to investigate post-mortem skin changes yields information via graphs and charts that provide robust insight on these changes. With passage of tie after death we conclude that the skin will be stiffer. More protracted time needs to be studied.

6. Next work

In the next work we will conduct more comprehensible studies on:

- More separated model for each time
- Investigate the effect of Death cause on the mechanical properties of the skin (i.e. hypovolemic shock due to blood loss or obstructive shock or neurogenic shock.
- Traction force amount should be calibrated and automated stage to provide more parametric pace.
- Testing of different animal anatomical locations.

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