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Viscoelastic Properties of Human Facial Skin – A Pilot Study

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BACKGROUND

- Facial prosthetic materials are used to replace missing eyes, noses, ears, etc., lost to trauma or disease.
- Current facial prosthetic materials do not accurately replicate the elasticity and feel of human skin at different locations on the face.
- Current materials have limited service lifetimes (1 - 2 years).
- New durable, "skin-like" polymers are needed.
- Key mechanical properties of facial skin must be known for constructing new materials. Presently these properties are largely unknown.

PURPOSE OF STUDY

To measure key viscoelastic properties of facial skin at different facial locations in a diverse population.

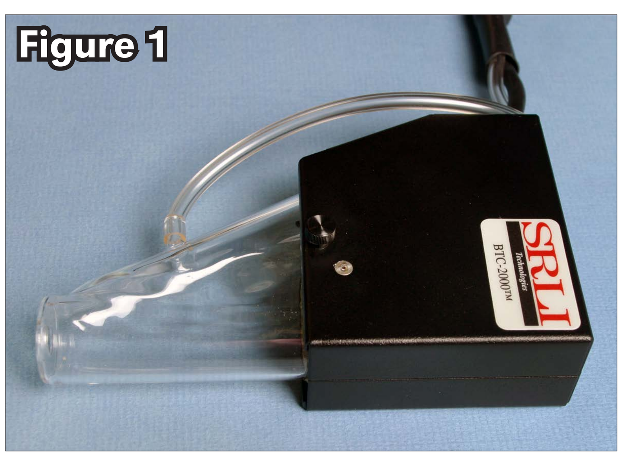
METHODS & MATERIALS

Human Subjects

- Human subjects approval (Omaha VA IRB #00644) and informed consent obtained
- 132 Subjects from Omaha and Lincoln, Nebraska, USA
- 31 African-American, 31 Asian, 34 Hispanic, 36 White
- 67 Female, 65 Male
- 46 age 19-29, 45 age 30-49, 41 age 50-70
- 52 military veterans, 80 non-veterans
- 6 facial locations: cheek, chin, tip of nose, forehead, back of ear, ear lobe
- Subjects asked to refrain from using facial lotions or make-up 24 h prior to study
- Inclusion criteria: Healthy skin in measurement area
- Exclusion criteria: Scarring, prosthesis, facial hair, jewelry in measurement area

Clinical Measurement (Figures 1 & 2)

- A hand-held vacuum-generating instrument measured viscoelastic properties (BTC-2000, SRLI Technologies, Nashville, TN)
- Erasable marker marked location of measurements
- Vacuum applied at 1.33 kPa/s until 20 kPa was reached, vacuum held for 10 s, vacuum released and relaxation measured for 3 s
- Stress-deformation data recorded and 6 viscoelastic properties measured



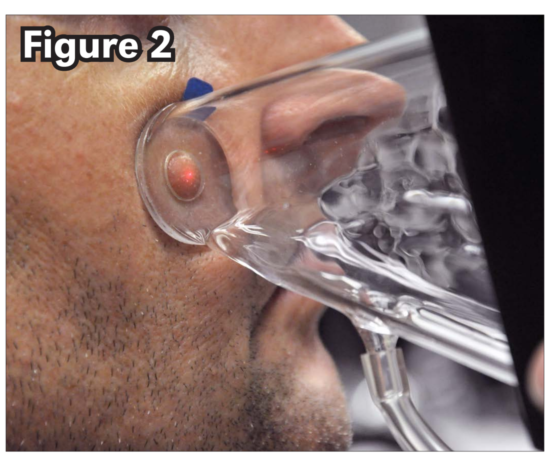


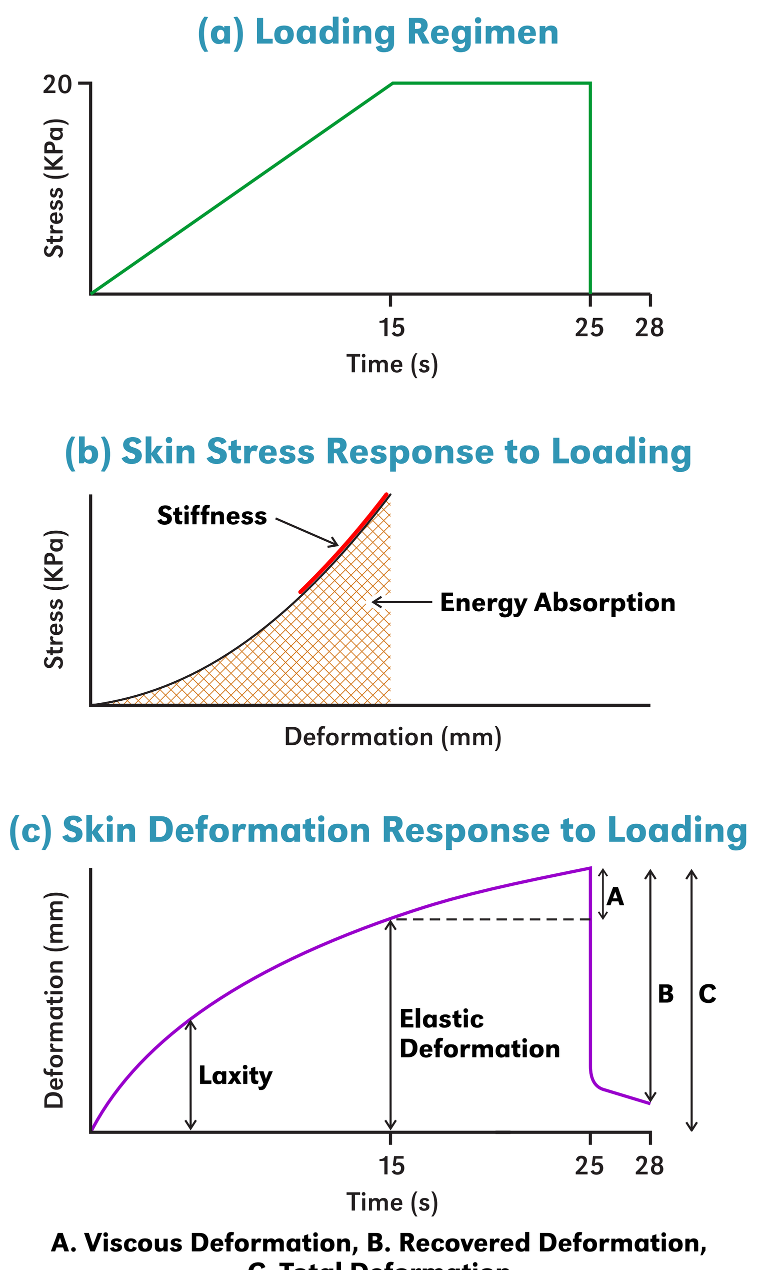
Figure 1. Glass chamber for applying vacuum to skin

Figure 2. Skin being drawn into chamber with laser target on skin. Movement of laser target is detected by an infrared sensor to measure deformation.

Viscoelastic Properties (Figure 3)

- Laxity – characterizes looseness of skin, measured as percent elastic deformation at low vacuum, where early change in slope in deformation-time curve occurs
- Stiffness – slope of linear portion of stress-deformation curve
- Elastic deformation – deformation obtained up to point of maximum vacuum
- Viscous deformation (creep) – amount of deformation occurring while vacuum is held constant; measures skin distensibility
- Energy – area under the stress-deformation curve up to maximum elastic deformation
- Elastic Recovery (%) – the ratio of recovered deformation following vacuum release to the amount of elastic deformation x 100
- Viscoelasticity Ratio – viscous deformation/elastic deformation, a reflection of continuity of elastin fibers

Figure 3



A. Viscous Deformation, B. Recovered Deformation, C. Total Deformation

Data Analyses

- Descriptive Statistics (means, standard errors of means) of viscoelastic properties
- Four-factor mixed linear model with full interaction to identify differences based on gender, age, race and facial location (p<0.05)

RESULTS

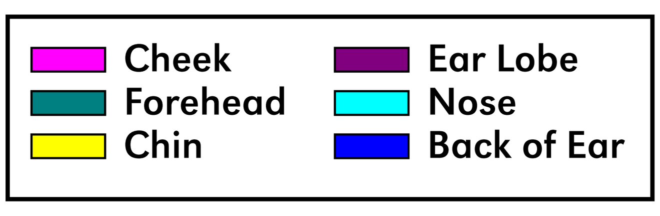


Figure 4

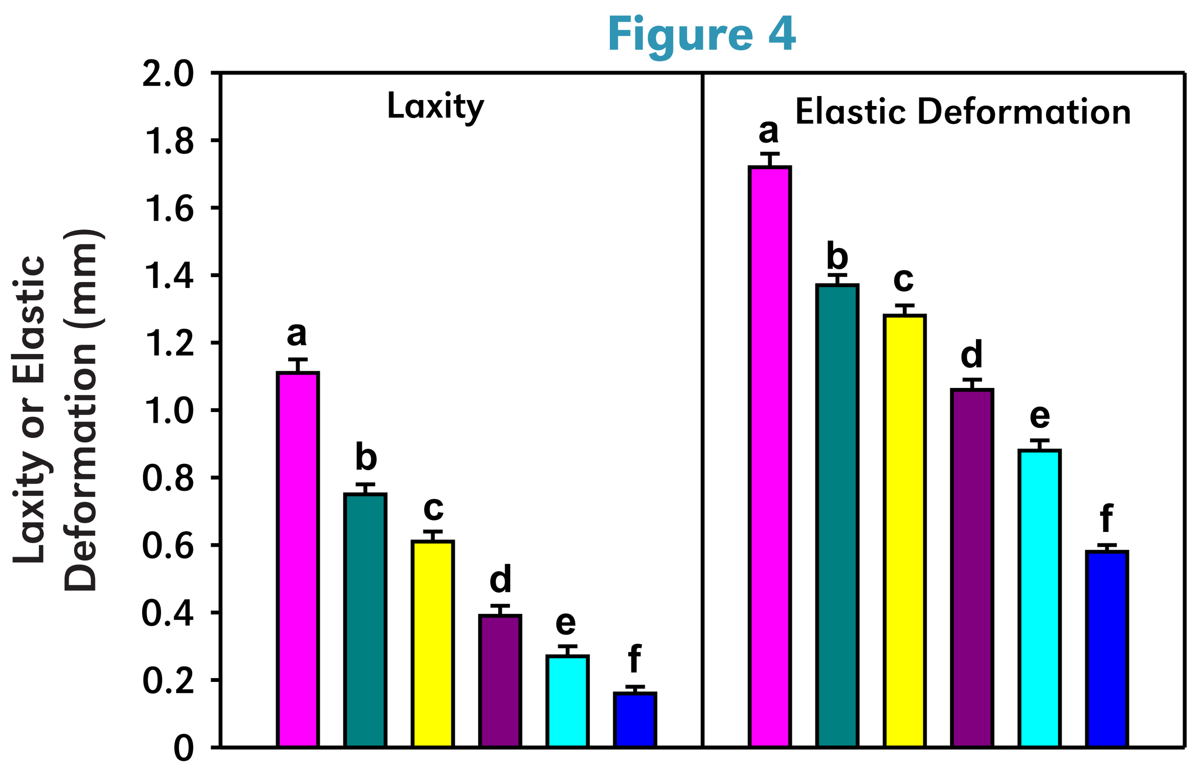


Figure 5

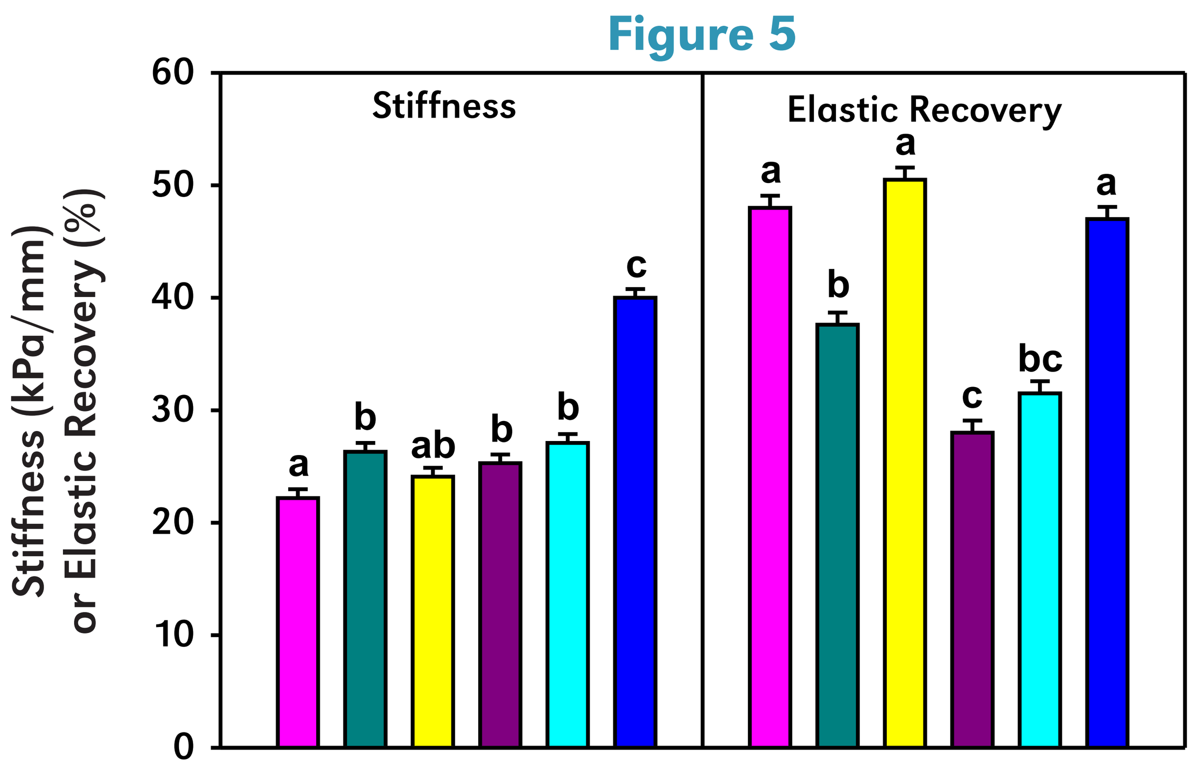


Figure 6

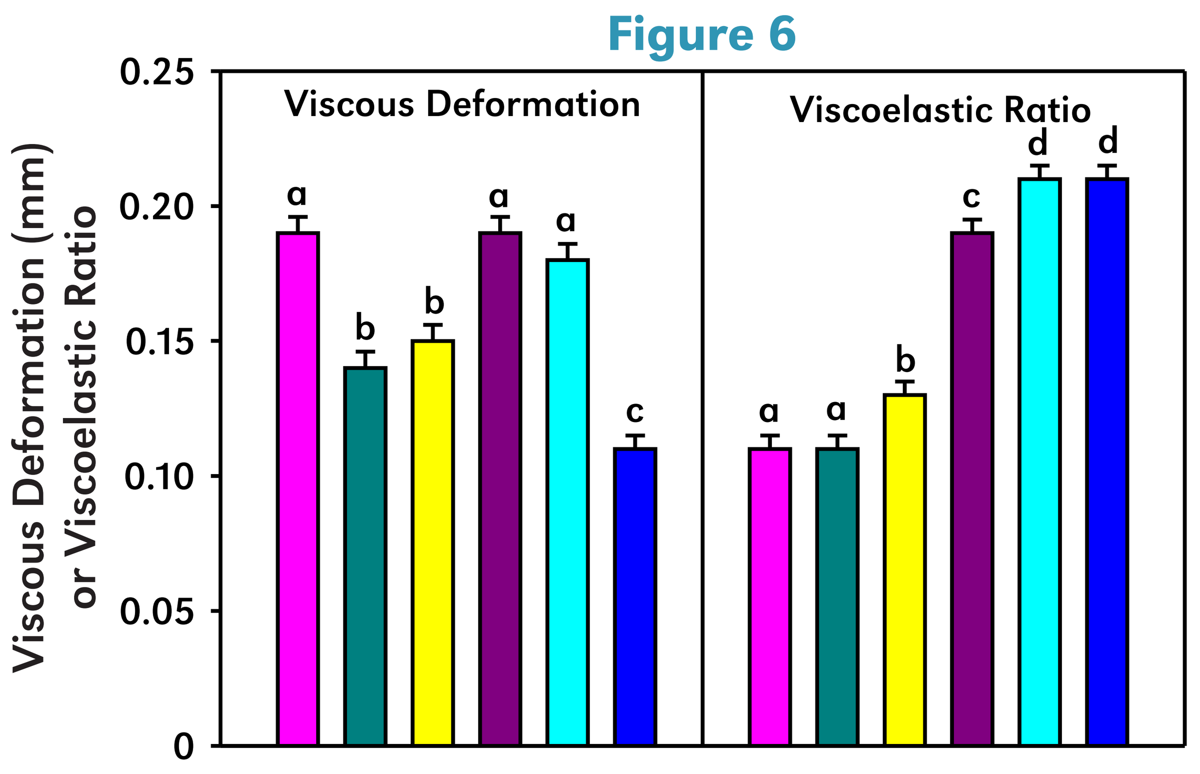


Figure 7

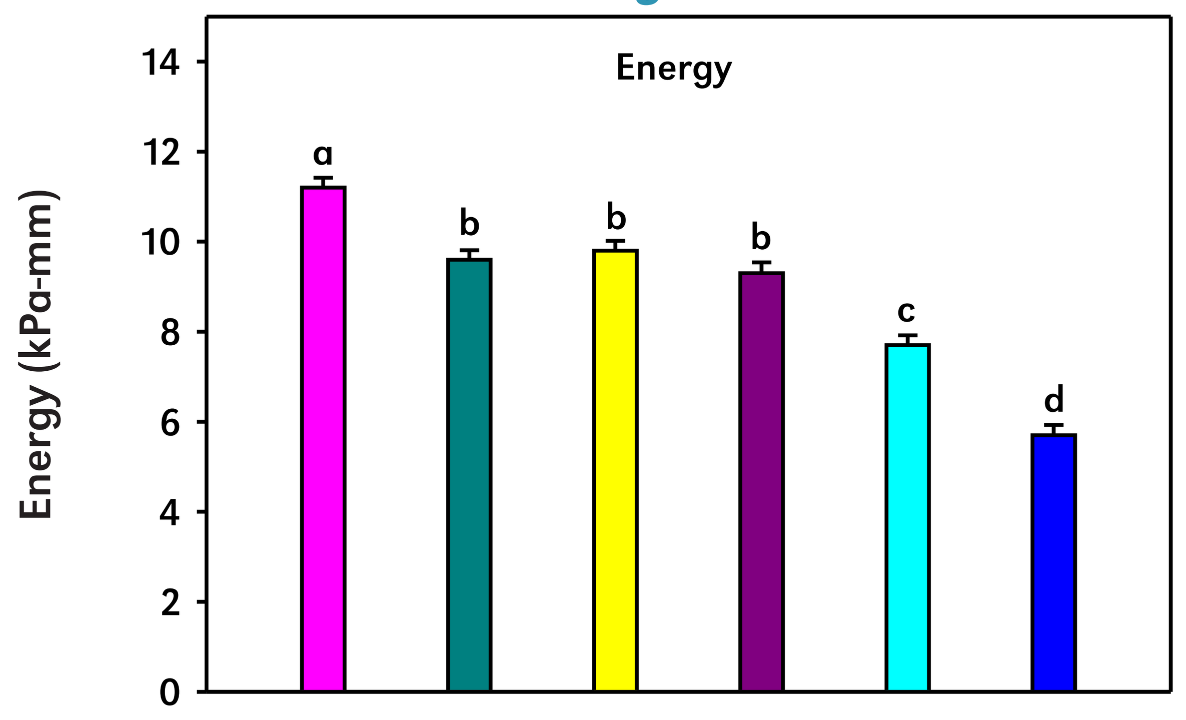


Table 1. Significant Property Differences Based on Gender (p<0.05)

Gender	Laxity (mm)	Elastic Deformation (mm)	Energy (kPa-mm)
Male	0.59 ± 0.022	0.59 ± 0.022	68.6 ± 1.34
Female	0.50 ± 0.022	0.50 ± 0.022	64.9 ± 1.36

Table 2. Significant Property Differences Based on Age (p<0.05)

Age	Viscous Deformation (mm)	Viscoelasticity Ratio
19 – 29	0.156 ± 0.0043^{a}	0.153 ± 0.0042^{a}
30 – 49	0.157 ± 0.0043^{a}	0.155 ± 0.0043^{a}
50 – 70	0.166 ± 0.0044^{b}	0.169 ± 0.0045^{b}

CONCLUSION

1. Facial location played a significant role in determining all material properties (p<0.05), whereas race/ethnicity did not significantly affect any property (p≥0.05).
2. Gender significantly affected laxity, elastic deformation and energy, and age significantly affected creep and viscoelastic ratio (all p<0.05).
3. Four of seven properties were similar for forehead, chin and nose, whereas the back of the ear was different from all other facial locations for all properties. This suggests different polymers are required to replicate different facial locations.

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