The effects of moisture on fingertip skin deformation during loading and slipping

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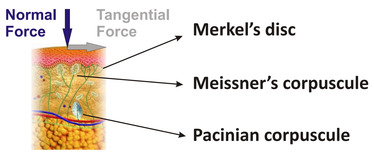
INTRODUCTION

During tactile interaction, skin deformation stimulates the mechanoreceptors, enabling the nervous system to become aware of the properties of the touched surface. Even on perfectly smooth, glassy surfaces, the fingertip skin deforms in complicated ways when slip occurs. The aim of the present study is to assess the effects of moisture content and interaction forces on the fingertip skin deformation occurring in this condition.

Background:



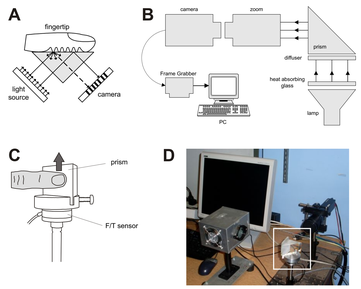
METHODS

A: Optical system used "frustrated total internal reflection" to obtain high contrast fingerprint images.

B: Components
- Diffused light source
- Prism
- CCD camera (640 x 484 at 60 Hz) + zoom

C: Interaction force and moments measured (F/T sensor: ATI Mini40).

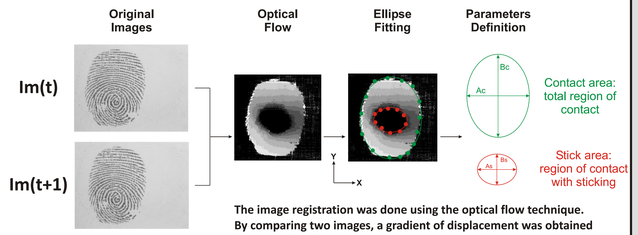
D: The complete system



Experiments

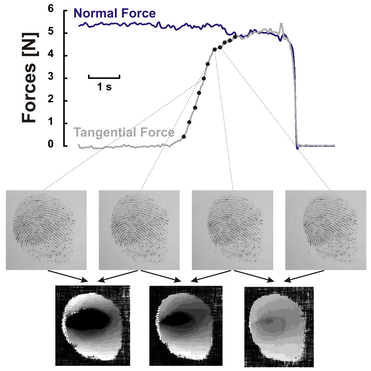
-10 subjects
- Focus on the period when the finger is between the stuck state and the sliding state
- 5 slippages for 6 given Normal Forces (0.2, 0.5, 1, 2, 5, 10N)
- Skin hydration measurements before and after slippages (Corneometer)

Image processing



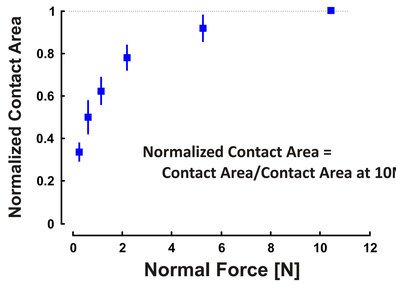
The image registration was done using the optical flow technique. By comparing two images, a gradient of displacement was obtained for each pixel. Black color corresponded to no displacement, gray level coded the level of displacement (the lighter, the greater).

TYPICAL TRIAL



- For a given Normal Force (NF), the Tangential Force (TF) increases until slipping occurs.
- During Tangential Force increase, images were sampled at constant time step.
- Pairs of images were compared with the Optical Flow technique.

Effect of Normal Force on CONTACT AREA



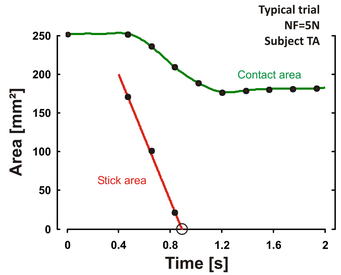
- For each subject, the Contact area was normalized with respect to the Contact area for Normal Force=10N (see Table 1).

- For this analysis, all measures of Contact area were done when Tangential Force = 0N.

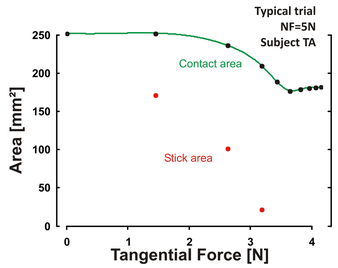
Table 1

Subjects	Contact Area at 10 N [mm²]
AC	224
AG	249
FH	228
GC	263
GT	177
MZ	183
RW	253
TA	288
VL	275
VM	251

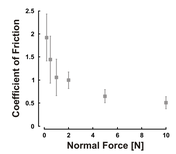
CONTACT and STICK AREAS



- Linear decrease of Stick area.
- Complete slipping occurs when Stick area = 0.

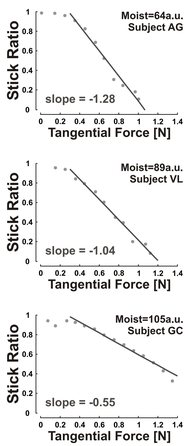


- Contact area decreases until slippage.
- Stick area decreases until slippage. At slipping: area = 0.

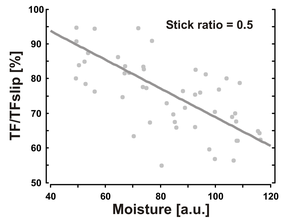


STICK Ratio

Normal Force = 1N

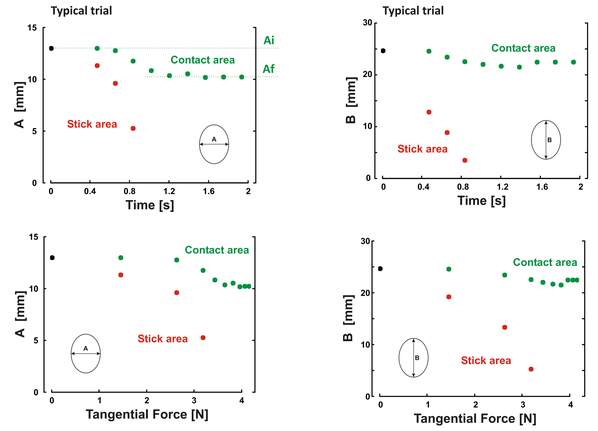


All Subjects
All Normal Forces



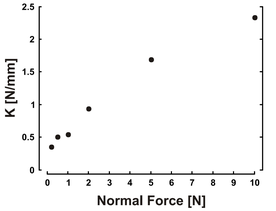
For a given Stick ratio, the more skin is hydrated, the farther it is from slipping.

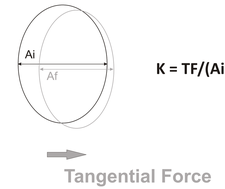
Ellipse PARAMETERS



Contact area mean compression for all subjects: 12.5% along the A-axis and 2.5% along the B-axis

Normal Force influences compressibility





K = TF/(Ai-Af)

Skin compressibility is strongly influenced by Normal Force.

CONCLUSIONS

- This study described the fingertip skin deformation by analysing the interactions between the Stick area and Contact area during loading and slipping.

- Fingertip skin moisture dramatically influenced the transition between stuck state and sliding state.

- These results suggest that cutaneous sensory feedback information could be influenced by moisture.

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